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# TRAINING EFFECTIVENESS EVALUATION: DEVICE 1D23, COMMUNICATION AND NAVIGATION TRAINER


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13. ABSTRACT


A study was performed to evaluate the training effectiveness of Communication and Navigation Training Device 1D23. Four objectives were addressed: Assess impacts of training in the device upon student dead reckoning navigation performance. Determine impacts of training in the device upon communication and navigation performance in point-to-point and airways navigation. Determine impacts of increased amounts of training in the device upon communication and navigation performance in dead reckoning, point-to-point, and airways navigation. Develop design oriented information for application to further training device designs. Flight grades and supplemental measures of student performance were analyzed. Instructor and student opinion data were obtained to supplement direct observations by the author. Training effectiveness of the device for dead reckoning, point-to-point and airways navigation was documented. No performance improvements were found as a result of the additional training which was examined. Design oriented information was developed.




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## FOREWORD

The Naval Training Equipment Center has a continuing interest in the evaluation of training to improve training device utilization, to develop information for use in future training device design, and last but not least, to improve the methodology and conduct of training evaluations. These goals were taken as objectives for the present effort.

With respect to training device utilization, the present study investigated the relation ship between training in Device 1D23, a new trainer, and subsequent performance in the airborne training phases. With respect to training device design, the present study evaluated the adequacy of certain advanced design features of Device 1D23 such as the generalized trainee station and automatic performance measurement capability. In addition, the use of current grading practices for evaluation purposes was also investigated. The experimental data provide evidence that current grading practices are not sensitive to changes in navigation performance and, perhaps, more important, that the implementation of certain experimental design conditions (namely control group data and objective performance measurement) are crucial to successful transfer-of-training evaluations.

William B. Boney
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TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

# LIST OF TABLES

# SECTION I

# INTRODUCTION

This report documents a training effectiveness evaluation of Device 1D23, Communication and Navigation Trainer. Purposes of the evaluation were to provide objective bases for assessing the training effectiveness of the device relative to its use in a specific syllabus of instruction, and to provide guidelines for future evaluations and training device designs. The evaluation centered upon the collection and analysis of student performance data and other information in a formal and systematic manner.

## DEVICE CHARACTERISTICS

Device 1D23 was a fixed base, digitally driven trainer which was designed to provide training in the cognitive aspects of basic aircraft navigation and practice in radio communication required in the operation of typical Navy aircraft such as the F-4J and the E-2A. It is described more fully in Reference 1.

The device recently was installed at Training Squadron Ten (VT-10), Naval Air Station, Pensacola, Florida, where it was used in basic Naval Flight Officer (NFO) training. During the evaluation it was used to provide training in the following:

Navigation communication techniques

Basic dead reckoning

Airways navigation

Solving relative motion problems

Aircraft fuel management

Integration of navigation aids

The device incorporated 40 identical student stations, each of which generally simulated the NFO cockpit of a typical Navy aircraft. All stations were capable of independent operation and maneuvering within a 1200 nautical mile problem area.

Each student station contained instruments, controls and displays to permit the student to communicate, make navigation inputs to the system, and make necessary inputs to the digital computer which drove the trainer. The

computer also drove instruments and displays in accordance with each student's inputs as he attempted to navigate over preplanned mission courses. The spectrum of training which was provided in the device is reflected by the system capabilities which were available at each student station. Each station contained the following:

- Magnetic compass
- Time display
- Airspeed/mach indicator
- Attitude indicator
- Pressure altimeter
- Radar altimeter
- Radio magnetic indicator
- Climb rate indicator
- Distance measuring equipment
- Navigational mode and data entry panel
- Audio recorder
- Communication navigation identification (CNI) panel
- CNI data entry panel
- Navigation computer display panel
- Inertial doppler control panel
- Communications headset
- Command and response control panel for trainer computer input
- Performance alarm panel
- General-purpose alpha-numeric display panel
- Fuel Flow Indicator

One of the unique features of the trainer was that all but three displays incorporated light emitting diode digital readouts. Only the magnetic compass, radio magnetic indicator, and the attitude indicator were analog displays.

The device utilized 11 preprogrammed training problems (TPs) which progressively varied in level of difficulty. Up to 40 student stations could be designated for training on any one of the TPs at any given time. Training on two different TPs could be independently undertaken at any given time, with up to 20 stations dedicated to each TP. The TPs provided the context for structured training, student cueing, knowledge of results (KOR) feedback, and automated student performance evaluation. For automated performance evaluation, each student's performance could be independently compared with that of an "ideal navigator." Student stations also could be operated independently of the TPs, thus providing the capability for unstructured practice. The TPs are summarized in Appendix A. A more detailed description of the TPs can be found in Reference 2.

Two sets of Instructor and Training Device Operator (TDO) consoles contained interactive graphics terminals and data entry keyboards for controlling the trainer, monitoring and controlling student stations, and communicating with student stations. During a typical training mission, one nstructor with two TDOs were required for each block of 20 student stations.

UTILIZATION CONTEXT

At the time of the evaluation study, basic NFO training required a minimum of 20 weeks at VT-10. Each class consisted of an average of 36 students. On a time basis, training consisted of approximately 60 percent academics (including training in Device 1D23) and 40 percent in-flight training. Before being assigned to a replacement air group (RAG), graduates of VT-10 were required to accomplish an additional six to 13 weeks of advanced training at other schools, depending upon the specialty for which they were preparing.

At VT-10 each student received approximately eight weeks of academic instruction prior to receiving training in Device 1D23. The students' first formal exposure to the device involved TPs 1 and 2, which were designed to introduce students to the operation and use of the trainer. Students then received training on TPs three through six. This training was followed by four in-flight dead reckoning navigation training flights in T-29 or C-114 aircraft. Following approximately two weeks of additional academic training, students received training on TPs 7, 8, and 10. This was followed by three training flights in T-39 aircraft. Point-to-point and airways navigation and communication techniques were emphasized during these flights. Following several days of additional academic training, students received training on TPs 9, 10, and 11. This training was followed by in-flight instruction in F-9 aircraft.

In addition to specified training in the device as is described briefly above, the device was kept available approximately four hours per day, during which time students could voluntarily come in for additional training.

Objectives set forth for the evaluation study were accomplished in the framework of device characteristics and utilization context as summarized above.

# SECTION II

# OBJECTIVES AND CONSTRAINTS

## OBJECTIVES

Four separate, yet related objectives were set forth for the training effectiveness evaluation study. They were:

> Assess impacts of training in Device 1D23 upon student dead reckoning navigation performance as demonstrated during in-flight training in the T-29 or C-114 aircraft.
>
> Determine impacts of training in Device 1D23 upon student communication and navigation task performance in the T-39 airborne training phase (point-to-point and airways navigation).
>
> Determine impacts of increased amounts of training in Device 1D23 upon student communication and navigation task performance in both the T-29/C-114 and the T-39 airborne training phases.
>
> Develop design oriented information and data for application to future training device designs.

Accomplishment of all study objectives was achieved within the context of several training situation constraints which are discussed below.

## CONSTRAINTS

Every evaluation study is subject to certain constraints. There are two purposes for describing the constraints which bounded the present study. The first is to define the limiting factors which impacted upon the planning and execution of the study for the purpose of qualifying the results of the study. The second is to make available information which may be of practical value in planning and executing similar evaluations.

A primary constraining factor was that training in Device 1D23 had been instituted prior to detailed planning and initiation of the evaluation study. This general factor resulted in several specific constraints, each of which is discussed in the following paragraphs.

Use of the trainer had been tightly integrated into NFO training at VT-10. Because of pipeline demands and limited instructional resources, major alterations to the existing use of the device or to in-flight training practices were judged to be unacceptably disruptive to training. Accordingly, the creation of special student control groups, which would have advanced to in-flight training without training in the device, had to be ruled out. Instructional personnel also were strongly opposed to special control groups on the basis that they felt the trainer was improving student performance and that students should not be deprived of this perceived benefit.

The fact that the trainer already was in use also cascaded into the area of student performance measurement. Reliable, task-oriented measurement is a virtual necessity for any type of device evaluation. Obtaining such measurement, however. frequently requires additional resources which may not be available without disrupting training or causing pipeline demands to go unmet.

Instructional resource limitations coupled with the need to maintain existing rates of student flow through VT-10 greatly constrained the measurement of student performance of dead reckoning navigation tasks. Student to instructor ratios of eight to one were common on dead reckoning training flights. At a minimum, improved measurement would have required an improved student to instructor ratio, as well as increased opportunities in-flight for students to act as the aircraft's lead navigator. Neither instructor, aircraft, nor pilot resources were sufficient to allow for meaningful improvements over normal grading practices for these flights. (Fortunately, the measurement problems was less severe for the T-39 airborne training phase, where the student to instructor ratio was one to one, and where training tasks could be better defined for measurement purposes.)

The preceeding constraints necessitated placing a heavier emphasis on the use of measures of dead reckoning, which could be obtained within the context of training as it existed. One such measure was flight grades. Any use of flight grades for comparisons of student performance before versus after introduction of the trainer was limited, however, because of changes in the application of grading standards shortly after the introduction of the device. Instructors felt that the trainer was helping to produce a better

quality product, and therefore applied grading standards more stringently for students who had received training in the device. Because of this "rubber yardstick", using grades as an index of student performance could be approached in only a very limited fashion.

Because of the above measurement constraints, the use of other types of evaluation data was explored. These included: frequency of student "downs" (one unsatisfactory grade on any performance element on any flight); frequency of Training Advisory Board (TAB) reviews of students (required following two "downs" in any training phase); and attrition rates during various training phase (e.g. percent of students not completing a phase). These data were not utilized for several reasons. First, they were not accessible in sufficiently detailed form within the temporal and fiscal limitations of the study. It was found, for example, that some of the necessary data were not centralized. Where data were centralized, they were coded and stored in keeping with quite different requirements, making them too ambiguous or incomplete for meaningful research application in a study such as the one reported here. Finally, the utility of any such data, including grades, was diminished by the fact that the calibre of students, as measured by Aviation Qualification Tests and Flight Aptitude Ratings, was declining during the same period when Device 1D23 was introduced.

Other measures of device effectiveness could not be used because of the philosophy for device utilization. Device 1D23 was not intended to replace or be used as a substitute for airborne training. Accordingly, measures of device effectiveness based upon savings in flight training were not appropriate.

Effectiveness of the trainer was addressed in a training context, not a fleet operational context. In-flight training in dead reckoning navigation (T-29 and 114 aircraft) and, communications, point-to-point navigation and airways navigation (T-39 aircraft) were selected in conjunction with VT-10 personnel as the most appropriate settings in which to measure any transfer of training from the device to related tasks in airborne settings. The measurement of training transfer to communication and navigation tasks in jet fighter aircraft (F-9 in-flight training phase) was not addressed because only two flights were involved and because they consisted primarily of indoctrination to low level visual navigation, formation flight, and aerobatics.

As a result of the above constraints, the study utilized flight grades, instructor opinions, and student

opinions for assessment of the effectiveness of the device for training in dead reckoning navigation. For communications, point-to-point, and airways navigation, the above measures were supplemented with more objective, instructor-generated measures of student performance.

Finally, results of the study apply to the utilization of the trainer at the time of the study and to in-flight training at that time. What is trained in the device, for example, is highly dependent upon the content of pre-programmed training problems. If the content of the training problems is markedly altered, then the effectiveness of the device may change accordingly. Similarly, as airborne communication and navigation task requirements change, the effectiveness of the trainer in preparing students to execute these tasks may change.

The balance of this report separately addresses each of the four objectives specified at the beginning of this section. Constraints of the study are not recited in the following sections. However, interpretations of the results of experimental aspects of the study are presented in keeping with the constraints.

# SECTION III

# TRAINING EFFECTIVENESS EVALUATION, DEAD RECKONING NAVIGATION

## OBJECTIVE

The objective for this aspect of the study was to assess impacts of training in Device 1D23 upon student dead reckoning navigation performance as demonstrated during in-flight training in the T-29 or C-114 aircraft.

## CONTEXT

The instructional syllabus established that the primary purpose of T-29/C-114 training flights was to introduce student NFOs to the flight environment and to make relevant all navigational instruction (Ref 3).

Each dead reckoning navigation training flight generally was comprised of seven to eight students, one instructor NFO, two pilots and a crew chief. Up to four students performed lead navigator dead reckoning tasks for approximately 1.5 hours during each training flight, which was approximately six hours in duration. When not acting as lead navigators, students performed tracker dead reckoning navigation tasks.

## METHOD

Two classes were selected for the purpose of comparing dead reckoning flight grades before versus after the introduction of training in the device. Class 408 was selected because it provided the best opportunity to examine flight grades before instructors had much collective opportunity to become more stringent in applying grading standards.

Class 407 was the other class and was selected for three reasons. First, class 407 did not receive training in the device. Second, it received training in the immediate timeframe of class 408. Third, instructor NFOs agreed that less tangible factors such as class spirit, motivation, student quality, and student relationships with class leaders and advisors were comparable for classes 407 and 408.

Twenty-three students were selected from each class for grade comparison purposes. The two groups were quite similar in terms of distributions of Flight Aptitude Rating (FAR) and Aviation Qualification Test (AQT) scores. FAR stanine scores for the class 407 group ranged from 3 through

9, with a mean of 6.4. AQT stanine scores for the class 407 group ranged from 4 through 9, with a mean of 7.2. FAR stanine scores for the class 408 group also ranged from 3 through 9, with a mean of 6.2. AQT stanine scores for this group ranged from 5 through 9, with a mean of 6.8.

Students in each class received five training flights, three of which were graded. Using standard evaluation procedures, instructor NFOs graded each student's performance following the flights. All flights were conducted in keeping with the T-29 Flight Syllabus (Ref 3).

Grading was done after each flight using standardized Aviation Training Forms and grading criteria (Refs 3 and 4). Using a four-point scale, a numerical grade of unsatisfactory (1), below average (2), average (3), or above average (4), was determined for each performance element which was itemized in the Aviation Training Form and which was applicable to the student's requirements during the flight. Performance elements for the training flights were: positions, winds, computations, use of navigation tools, lead navigator performance, preflight, logs and charts, emergency drill, response to instruction, and overall performance. As is the case with practically all such grading systems, the resulting grades are rather subjective because of latitudes which exist for instructor judgement and interpretation of student performance in relation to rather generally defined performance elements.

Overall flight grade was computed for each student in each group for each graded flight by averaging numerical grades across all performance elements. Resulting flight grades for the two groups were statistically compared for each flight as well as across all flights. The factorial analysis of variance statistical test was used (Ref 5).

As a separate activity, instructor NFOs were interviewed regarding their observations and opinions of student performance before versus after the initiation of training in Device 1D23. The interviews were supplemented by a standardized questionnaire.

## RESULTS

FLIGHT GRADES. Table 1 presents mean flight grades for students in each of the two groups for the three graded flights (flights 2,4, and 5), as well as averages across flights. Mean grades for the class 408 group (which received training in the device) were somewhat higher for each of the three flights, as was their average across flights. Statistically, however, none of the differences between groups was

significant at the .05 level[1]. Although both groups did exhibit statistically significant (P = .01)[1] improvements in grades from the first to third graded flight. Rates of improvement were not statistically comparable for the two groups. It can be concluded, therefore, that both groups performed essentially the same and that slightly better grades of the class 408 group can be reasonably attributed to chance factors rather than training in Device 1D23.

TABLE 1. AVERAGE FLIGHT GRADES, DEAD RECKONING TASKS

| | First Graded Flight | Second Graded Flight | Third Graded Flight | Average Across Flights |
|---|---|---|---|---|
| Class 407 Group | 2.98 | 3.05 | 3.10 | 3.04 |
| Class 408 Group | 3.01 | 3.13 | 3.18 | 3.10 |

During the course of the study, several instructor NFOs indicated that they felt students who had received training in the device were achieving more above average grades than students who had not received such training. This possibility was explored by determining the number of above average grades received by each student in either group on any performance element during the three graded flights. The resulting information is summarized in Table 2.

The top portion of Table 2 presents mean numbers of above average grades for students in each group. Means are separately presented for each graded flight, as well as averaged across all flights. On the first and third flights, as well as on the overall flight average, students in the class 408 group tended to receive more above average grades. Differences between group means were statistically compared using the t-test for independent measures. Comparisons were made separately for each flight and for the overall flight averages. Results of the tests were far from being

[1] Indicates the probability that differences between the two groups could have resulted from chance factors. The .05 level is used throughout as the maximum cutoff probability for determining statistical significance.

statistically significant at the .05 level. It can be reasonably concluded, therefore, that the observed differences were due to chance factors.

Mean percents of grades which were above average were similarly compared for the two groups. Again, slight differences appearing to favor the class 408 group were not statistically significant.

Percents of students in each group who received above average grades also were compared separately for each graded flight, as well as averaged across all flights. The procedure recommended by Blommers and Lindquist (Ref 6), was used for statistically comparing the percentages. Results of the tests were far from being significant at the .05 level. It can be reasonably concluded, therefore, that minor variations between groups were due to chance factors.

Although none of the analyses of flight grades showed statistically reliable improvements in student performance on airborne dead reckoning tasks as a result of training in the device, instructor questionnaire responses indicated that numerous improvements were evident.

TABLE 2. SUMMARY OF ABOVE AVERAGE GRADE DATA, DEAD RECKONING TASKS

| | | First Graded Flight | Second Graded Flight | Third Graded Flight | Average Across Flights |
|---|---|---|---|---|---|
| Mean No. of Above Average Grades Per Student | 407* | 1.13 | 1.83 | 1.70 | 1.55 |
| | 408* | 1.21 | 1.78 | 2.26 | 1.75 |
| Mean Percent of Grades Which Were Above Average | 407 | 11.4 | 17.6 | 16.6 | 1.52 |
| | 408 | 11.9 | 17.6 | 22.7 | 1.74 |
| Percent of Students with Above Average Grades | 407 | 78.2 | 69.5 | 78.2 | 75.3 |
| | 408 | 65.2 | 78.2 | 82.6 | 75.3 |

* Class groups

INSTRUCTOR QUESTIONNAIRE RESPONSES. A frequently overlooked source of valuable information is individuals who have extensive, day-to-day experience with the device or procedure being evaluated. In the present study, steps were taken to

ensure that instructor observations, opinions and viewpoints would not be overlooked. This was done by interviewing a number of instructor NFOs and consolidating content of the interviews and other information items to form a standard instrument (questionnaire). Rating scales used in the questionnaire were reviewed with a sample of instructors to ensure that they had meaning to the instructional community.

The resulting questionnaire, shown in Appendix B, was completed by all instructor NFOs and instructor pilots who were involved with training in Device 1D23, T-29, C-114, or T-39 aircraft during the period when the device was introduced.

The questionnaires were completed at the end of the data collection period. Fourteen instructor NFOs responded to elements of the questionnaire which were applicable to transfer of training from Device 1D23 to airborne dead reckoning navigation tasks. Their responses are summarized below.

Instructor NFOs were asked to rate how much value they felt training in Device 1D23 had in preparing students for T-29/C-114 training flights. Response options were: negative value, no value, minimal value, moderate value, and high value. Fourteen percent responded that the training was of moderate value. The remaining 86 percent indicated that the training had high value.

The second question, also of an overall nature, was intended to examine the general magnitude of any improvements in student performance which may have been evident following the introduction of training in Device 1D23. To do this, instructors were asked to compare general student performance on each of the training flights before and after introduction of the device. A majority (71 percent) indicated that overall student performance on the first dead reckoning training flight following introduction of the device was equivalent with performance which used to be observed on the third flight before the device was introduced. A majority (73 percent) also rated the second flight following training in the device as equivalent with the third flight before the device. Ninety percent rated the third flight following training in the device as equivalent with the fourth flight prior to the device. Finally, 67 percent rated the fourth flight following training in the device as being equivalent with the fifth flight prior to the device.

Irrespective of lack of differences associated with grades, instructor NFOs were consistent in their views that overall improvements in student dead reckoning performance resulted from training in the device. A third questionnaire item was designed to examine these views in greater detail. The item consisted of 38 task activities required of students during dead reckoning navigation training. The activities were clustered under four main topic areas. Instructors were asked to rate how well they felt training in the device prepared students to execute each of the task activities.

Table 3 summarizes results of the ratings. An "X" in the columns of the table shows median instructor ratings. It is notable that none of the consensus (median) ratings fell within the categories of hurts greatly or hurts some. Only three task activities were rated as having not been influenced by training in the device (No Effect category). These were: identifying restricted areas, preflighting logs, and preparing flight plans. Median ratings for all remaining task activities indicated that they benefited some or greatly as a result of training in the device.

Instructors also were asked to address the subject of substituting additional trainer time for flight time. To best interpret instructor responses, it must be pointed out that the fifth dead reckoning training flight was eliminated shortly after training in the device was instituted. Elimination of the flight should not be attributed to the trainer, however. It had been felt for some time that the fifth flight was not productive, and instructors indicated that the flight would have been eliminated regardless of the trainer. None the less, some reduction of in-flight training had occurred in the general timeframe during which instructors were asked to address the possibility of additional cuts in in-flight training.

Instructor responses were about evenly split when asked whether they felt additional training in Device 1D23 could be substituted for any of the dead reckoning training flights. Fifty-four percent responsed yes; 46 percent responded no.

The instructors were asked to elaborate upon their responses to substituting trainer time for flight time. Those who felt that flight time could not be compensated for by additional trainer time cited numerous factors associated with what typically is called "the realism of flight." The factors generally fell into two related categories. One category centered upon the psychological pressures of flight, including: correctly communicating with the pilot and crew; being in charge of an aircraft's

flight path; stress resulting from noise and temperature; and having to continue performing in spite of fatigue, nausea, uncertainty, hazards, or emergencies. A second category centered upon more physical aspects of flight, including: aircraft movement and responses to turbulence; in-flight emergencies; equipment malfunctions and failures; marginal reception on navigation aids, including the breaking of lock on stations; noisy communication channels; receiving erroneous instrument readings from pilots' and pilot errors in flying command headings. Content of the second category appears to offer a number of suggestions for ways to modify training in Device 1D23 to enhance its utility in preparing students for inflight performance.

TABLE 3. SUMMARY OF TASK ACTIVITY RATINGS, DEAD RECKONING

| | Hurts Greatly | Hurts Some | No Effect | Helps Some | Helps Greatly |
|---|---|---|---|---|---|
| **PREFLIGHT PLANNING & PREPARATION** | | | | | |
| Interpreting charts | | | | X | |
| Identifying restricted areas | | | X | | |
| Plotting courses | | | | X | |
| Using correct symbology | | | | X | |
| Selecting radio nav aids | | | | X | |
| Preflighting logs | | | X | | |
| Preparing flight plans | | | X | | |
| **MEASURING AND COMPUTING** | | | | | |
| Using CR 2/3 computer | | | | X | |
| Using plotter & divider | | | | | X |
| Determining TAS | | | | X | |
| Determining ground speed | | | | X | |
| Determining ETA | | | | X | |
| Determining wind direction/velocity | | | | | X |
| Determining drift angle | | | | | X |
| **NAVIGATING** | | | | | |
| Dead reckoning procedures | | | | | X |
| Understanding radials from nav aids | | | | | X |
| Plotting accurate TACAN fixes | | | | | X |
| Plotting multiple LOPs | | | | | X |
| Advancing/Retarding LOPs | | | | | X |
| Plotting EPs | | | | | X |
| Applying variation | | | | X | |
| Converting between mag & true heading | | | | X | |
| Plotting track, no-wind, wind lines | | | | X | |
| Using correct DR symbology | | | | X | |

TABLE 3. SUMMARY OF TASK ACTIVITY RATINGS, DEAD RECKONING (Cont)

| | Hurts Greatly | Hurts Some | No Effect | Helps Some | Helps Greatly |
|---|---|---|---|---|---|
| NAVIGATING (continued) | | | | | |
| Dead reckoning ahead | | | | X | |
| Correctly applying draft angle | | | | X | |
| Determining headings to fly | | | | X | |
| Filling out logs | | | | X | |
| Communicating with pilot | | | | X | |
| INTEGRATION OF KNOWLEDGE | | | | | |
| Getting it all together | | | | X | |
| Interpreting instruction | | | | X | |
| Keeping oriented relative to aircraft position | | | | X | |
| Keeping oriented relative to direction to checkpoints | | | | X | |
| Pacing tasks to "keep ahead of the aircraft" | | | | X | |
| Anticipating what would occur in flight | | | | | X |
| Understanding spatial relationships | | | | X | |
| Identifying incorrect Nav inputs or solutions | | | | X | |
| Identifying procedural and computational errors | | | | X | |

Instructors who indicated that trainer time might be substituted for flight time were asked to comment on what additional training in the device would be appropriate. A majority of those responding suggested additional training which would be patterned after the lead-tracker navigator structure used in dead reckoning training flights. They pointed out that such additional training, however, could be valuable only if each student was afforded a reasonable opportunity to act as lead navigator and if sufficient instructional personnel were available to work with and debrief students. A second recommendation was to cut in-flight training in half, and provide extra trainer or in-flight practice only for weak students. Implementation of this recommendation, of course, would require improved methods for assessing student proficiency. Along this line, a recommendation also was made to substitute one graded flight for a graded trainer session. This recommendation was predicated upon using the trainer's computer and software for objective, unbiased evaluation of student proficiency.

Instructors who indicated that trainer time could not be substituted for flight time were asked to suggest modifications to the trainer and to TPs which might make it possible to make such substitutions. A number of recommendations were made, including: improve student-to-instructor ratio to facilitate the diagnosis of student learning problems and allow for more adequate debriefings; add static and communications patter to radio communications simulation; degrade simulated reception on radio navigation aids, to include breaking of lock at appropriate aircraft headings and attitudes; incorporate unexpected route changes, such as those resulting from vectoring; ensure that students all have sufficient opportunities to act as lead navigators in training patterned after the lead-tracker navigator structure used in-flight; and add a motion capability to the trainer.

In two separate questions, instructors were asked to separately list elements of training in Device 1D23 which they felt had the best value or the least value in preparing students for in-flight dead reckoning training. Factors frequently listed as best values included: training in procedures and motor skills associated with the use of navigation tools; forcing students to operate under time pressures, pace their tasks, time-share among tasks, and organize tasks on priority bases; training in the use of flight logs, including which items are most important and how to obtain them; and preparing students for the lead-tracker roles which they assume in flight training. Less frequently listed values were: training in the selection of suitable navigation aids; development of an improved understanding of radials and spatial relationships; and facilitating student interpretation of instruction.

Factors listed as having the least value included: voice communications training; training as lead navigators in training problems designed to emulate the lead-tracker navigator structure used in dead reckoning training flights; and student log keeping and computational practice. Both of the latter factors were affected by the inability of instructors to devote sufficient time to monitoring individual student performance because of characteristically high student-to-instructor ratios.

Finally, instructors were asked to rate the concept of using Device 1D23 to train all students to at least the same, standardized performance levels prior to allowing them to advance to in-flight dead reckoning training. Response options were: very undesirable, possibly undesirable, no opinion, possibly desirable, and very desirable. Fourteen percent rated the concept as possibly undesirable; 22 percent

rated as possibly desirable; and 64 percent as very desirable. Several apprehensions were expressed, however, even by individuals who rated the concept as desirable. The apprehensions centered around the ability to objectively determine student proficiency in the device and the possibility that students would queue up due to inabilities to demonstrate proficiency, thus complicating student scheduling. One instructor also pointed out that a small percentage of students do not appear to fully grasp the meaning of navigation tasks until they are exposed to in-flight training; therefore, placing too strong an emphasis on evaluating them in the device could be unfair.

## CONCLUSIONS

Based solely upon statistical analysis of flight grades, it would have to be concluded that training in Device 1D23 had no effect upon the proficiency with which students were able to execute dead reckoning navigation tasks in an airborne setting. It is felt, however, that reliable conclusions regarding the training effectiveness of Device 1D23 cannot be drawn from flight grades alone.

Regardless of attempts to achieve objectivity and standardization, grades are basically subjective measures of performance. As such, they may not possess necessary research sensitivity to detect the effects of changes in instruction. Flight grades were used in the present study primarily because they constituted the only practically available measure of in-flight dead reckoning performance. They also were used because the possibility existed that standardized student evaluation practices might have rendered them sufficiently sensitive to be of research value. Based upon other information developed during this aspect of the study, it is felt that grades were not sufficiently sensitive to warrant the conclusion that training in the device did not result in improved dead reckoning performance.

The strength and consistency of instructor opinion data support the conclusion that training in Device 1D23 has resulted in improvements in virtually every aspect of student confidence and performance in the execution of dead reckoning tasks in an airborne setting.

Evidence also was found to support the conclusion that the first six training sessions in the device (including two purely introductory sessions) were approximately the equivalent of the first two dead reckoning training flights. This conclusion is based upon the consensus instructor viewpoint that overall

student performance on the first flight after the introduction of training in the device was equivalent with overall student performance which used to be observed on the third flight prior to the trainer.

Based upon the above information, it would also appear reasonable, on an exploratory basis, to reduce the number of dead reckoning training flights from five to approximately three.

It also appears reasonable to conclude that the training effectiveness of the device might be improved by effecting changes in device software to better simulate characteristics of the in-flight environment (e.g., noisier voice communications channels and marginal radio navigation aid signals), improve the device's automated performance measurement capability, and provide additional lead navigator practice during simulations of T-29/C-114 training flights.

SECTION IV

# TRAINING EFFECTIVENESS EVALUATION, T-39 PHASE

## OBJECTIVE

The objective for this aspect of the study was to determine impacts of training in Device 1D23 upon student communication and navigation task performance in the T-39 airborne training phase (point-to-point and airways navigation).

## CONTEXT

The instructional syllabus (Ref 7) established that a primary purpose of the T-39 training flights was to enable students to apply all basic navigation procedures for Tacan point-to-point and airways navigation while in a jet flight environment. Additionally, the flights were designed to provide students with cockpit familiarization and additional instruction in mental dead reckoning and communications procedures.

Each T-39 training flight consisted of three students, one instructor NFO and an instructor pilot. Three training flights were required for each student. Each flight, summarized below, varied in terms of student task requirements.

The first T-39 training flight was a point-to-point flight consisting of three segments, each of which required approximately 45 minutes. During each segment, students would perform one of three task clusters. One cluster involved navigation of the aircraft and execution of fuel management procedures. The second cluster involved communications outside the aircraft, and included cockpit familiarization. The third cluster involved tracker navigation and maintaining a jet log. Students rotated positions in the aircraft so that each student was provided an equal opportunity to perform the various task clusters during one of the three flight segments.

The second flight was an airways navigation flight. It, too, was divided into three 45 minute segments to allow each student an equal opportunity to perform differing task clusters. One cluster required navigation of the aircraft, execution of fuel management procedures, and communication outside the aircraft. The second cluster involved executing copilot duties. The third cluster involved tracker navigation and maintaining a jet log. Students rotated positions in the aircraft so that each was provided an equal opportunity to perform the various task clusters during one of the three flight segments.

The third flight actually consisted of three mini airways flights, each of which was approximately one hour in duration. During each mini flight, one student performed all task clusters, from takeoff through landing, from the copilot's seat. The remaining two students performed tracker navigation tasks.

During all flights, when a student was acting as the lead navigator or when he was performing communications or copilot duties, he was under the direct observation of an instructor NFO or instructor pilot. This one-to-one student-to-instructor ratio greatly facilitated the measurement of student performance.

METHOD

Two classes (407 and 408) were selected for the purpose of comparing flight grades before versus after the introduction of training in Device 1D23. They were selected for reasons previously discussed in Section III. Twenty-three students were selected from each class for grade comparisons. They were the same students selected for comparison of dead reckoning flight grades.

In anticipation of the training effectiveness evaluation and the need for more objective, task-oriented measures of student performance, Navy personnel, including instructors at VT-10, developed a supplemental performance evaluation form. Content of the form is defined in Table 4. Student errors were recorded on supplemental data forms as they occurred in flight.

The forms were used in addition to flight grades to supplement the evaluation of performance of students in class 407 during their T-39 training flights. Since this class did not receive training in the device, performance data developed from the forms provided a baseline against which to compare performance of a class which had received training in the device.

Class 416 was selected for comparison with class 407 using the supplemental measures of student performance. Class 416 was selected for four reasons. First class 416 had received training in the device. Second, the class was accessible for performance measurement within the timeframe of the study. Third, instructors agreed that less tangible factors such as class spirit, motivation, student quality, and student relationships with class leaders and advisors were comparable with those of class 407. Fourth, it was possible to select a group of 23 students from class 416 which was comparable with the class 407 group in terms of FAR and AQT scores. For the class 407 group, FAR stanine

TABLE 4. CONTENT OF SUPPLEMENTAL PERFORMANCE EVALUATION FORMS

| Measure | Description |
|---|---|
| Number of Voice Communication Errors | Number of times when a student made content or format errors during a radio transmission. |
| Number of Missed Calls | Number of times when a student tasked with monitoring voice communications failed to identify a transmission to the aircraft. |
| ETAs, Number of Minutes Off | Average error in minutes between computed estimated time of arrival and actual time of arrival. |
| Number of Wrong Way Turns | Number of times when a student directed the pilot to turn the aircraft in a direction opposite that which was required. |
| Number of Heading Errors | Number of times when a student directed the pilot to fly a heading which was at least 10 degrees different from the heading which was required. |
| Number of No. 2 Needle Reading Errors | Number of times when a student misread the displayed value of the No. 2 needle of the Radio Magnetic Indicator by at least 5 degrees. |
| Number of Altimeter Reading Errors | Number of times when a student misread the altimeter by at least 1,000 feet. |
| Number of Departure Errors | Number of times when a student failed to or was unable to direct the pilot through normal instrument departure and clearance compliance procedures. |

TABLE 4. CONTENT OF SUPPLEMENTAL PERFORMANCE EVALUATION FORMS (continued)

| Measure | Description |
|---|---|
| Number of Enroute Errors | Number of times when a student failed to or was unable to direct the pilot through radial tracking, radial intercept, station passage or wind correction. |
| Number of Turn Point Errors | Number of times when a student failed to or was unable to execute standard turn point procedures of giving the pilot the new course, obtaining fuel flow and quantity information, giving the pilot a new heading to fly at minimum DME, directing the aircraft onto the outbound radial, and computing estimated time of arrival at the next turn point. |
| Number of Fuel Management Errors | Number of times when a student failed to or was unable to correctly determine fuel required for the next leg and fuel required for the balance of the flight. |
| Number of Approach Errors | Number of times when a student failed to or was unable to direct the pilot through normal instrument approach and clearance compliance procedures. |
| Minutes to get on Radial | Number of minutes between the time when a student should have begun to intercept a radial (eg., at a turn point) until he had directed the aircraft onto the radial, averaged across all radial intercepts by a student during a flight. |

TABLE 4. CONTENT OF SUPPLEMENTAL PERFORMANCE EVALUATION FORMS (continued)

| Measure | Description |
|---|---|
| Percent of Time on Radial | Number of minutes a student maintained the aircraft on a radial divided by the total number of minutes required to fly the leg, averaged over all radials tracked by a student during a flight. |

scores ranged from 3 through 9, with a mean of 6.4. AQT stanine scores ranged from 4 through 9, with a mean of 7.2. For the 23 students selected from class 416, FAR stanine scores also ranged from 3 through 9, with a mean of 6.4. AQT stanine scores ranged from 4 through 9, with a mean of 7.0.

Students in each class group received three training flights, all of which were graded. Supplemental performance measures were collected for all students in classes 407 and 416. All flights were conducted in keeping with the T-39 flight syllabus (Ref 7).

Grading was done after each flight using standardized Aviation Training Forms and grading criteria (Refs 7 and 8). The four point scale previously described in Section III was used to determine a grade for each performance element which was itemized in the Aviation Training Form and which was applicable to the student's requirements during the flight. Performance elements for the training flights were: preflight planning, communications procedures, TACAN point-to-point, fuel management, use of radio navigation aids, use of FLIPs and publications, departure procedures, enroute procedures, approach procedures, emergency procedures, preflight and postflight inspections, instrument interpretation, mental dead reckoning, response to instruction, and aircraft servicing.

An overall flight grade was computed for each student in the class 407 and 408 groups for each flight. This was done by averaging numerical grades across all performance elements. Resulting flight grades for the two groups were statistically compared for each flight as well as across all flights. The factorial analysis of variance statistical test was used (Ref 5).

Data derived from the supplemental performance evaluation forms were subjected to statistical test using both univariate (factorial analysis of variance) and multivariate (multiple discriminant analysis) techniques (Ref 5). The multiple discriminant analysis technique is briefly described in Appendix C.

As a separate activity, instructor NFOs were interviewed regarding their observations and opinions of student performance during T-39 flights before versus after the initiation of training in Device 1D23. The interviews were supplemented by a questionnaire.

## RESULTS

FLIGHT GRADES. Table 5 presents mean flight grades for students in the class 407 and 408 groups for each of the T-39 flights, as well as averaged across all flights. Mean flight grades were identical for both groups on the first flight. On the second flight, grades were slightly higher for the class 407 group (which had not received training in the device). Grades were virtually identical for both groups on the third flight. Averaged across all flights, grades were slightly higher for the class 407 group. The analysis of variance statistical test of the grades revealed that none of the differences between groups was significant at the .05 level[2]. It can be concluded, therefore, that slight differences in flight grades between the two groups can be reasonably attributed to chance factors rather than to effects of training in Device 1D23.

TABLE 5. MEAN FLIGHT GRADES, T-39 FLIGHTS

| | First Flight | Second Flight | Third Flight | Average Across Flights |
|---|---|---|---|---|
| Class 407 Group | 3.02 | 3.13 | 3.06 | 3.07 |
| Class 408 Group | 3.02 | 2.99 | 3.04 | 3.02 |

[2] Indicates the probability that differences between the two groups could have resulted from chance factors. The .05 level is used throughout as the maximum cutoff probability for determining statistical significance.

SUPPLEMENTARY PERFORMANCE MEASURES. Supplementary performance data previously described in table 4 were statistically analyzed. For the analyses, numbers of wrong way headings and heading errors in excess of 10 degrees were combined into a single measure called number of wrong headings. Number of minutes to get on the radial and percent of time on radial were analyzed only for the second and third flights. The first flight was not an airways flight, and the measures were not applicable.

The supplementary data were analyzed using multiple discriminant analysis and factorial analysis of variance. One set of analysis of variance tests was used to compare student performance separately for each of the three flights as well as across flights. This set of tests was computed for each measure except time to get on radial and percent of time on radial. An additional set of analysis of variance tests was computed to compare student performance separately for the second and third flights as well as across both flights for all 13 measures. Results obtained from the multiple discriminant analyses and the analysis of variance tests were virtually identical. Accordingly, only results of the analysis of variance tests are reported.

Two measures showed highly comparable rates of change between the first and third training flights for the two groups. Altimeter reading errors for both groups increased from an average of .37 per student on the first flight to an average of .89 per student on the third flight. This change was statistically significant at the .05 level. Turn point procedural errors for both groups decreased from an average of 1.65 per student on the first flight to 1.00 per student on the third flight. This change also was statistically significant at the .05 level.

Statistical analysis also showed that several measures exhibited differential rates of change across flights for the two groups. Rates of change of number of RMI number two needle reading errors were similar for both groups between the first and second T-39 flights. Between the second and third flights, however, average numbers of reading errors per student for the class 407 group increased from .22 to .83. The average number of reading errors per student for the class 416 group increased only from .04 to .09.

Similarly, numbers of fuel management errors were statistically comparable for both groups on the first flight. However, the class 416 group exhibited significantly ($P = .05$) better performance on both second and third flights.

ETA errors were significantly (P = .01) smaller for the class 406 group only on the first flight. On the second and third flights, both groups' errors were statistically comparable.

In a reverse trend, numbers of turn point errors were comparable for both groups on the first flight. The class 407 group showed no meaningful decline in these errors through the third flight, while class 416 group errors declined from an average of 1.91 errors per student on the first flight to .52 errors per student on the third flight.

Departure errors also exhibited statistically (P = .01) different trends across flights for the two groups. The Mean number of errors per student in the class 407 group was .26 on the first flight, rising to .78 on the second flight, and then declining to .52 on the third flight. For the class 416 group, mean errors were higher on the first flight (.52 errors per student), but they declined sharply to .04 on the second flight. Errors then rose to an average of .70 per student on the third flight. Reasons for the marked divergence of error patterns for the two groups is not clear. Averaged across flights, the difference between groups was not statistically significant.

None of the remaining six measures showed any statistically reliable changes across flights.

Averaged across flights, statistically significant performance improvements were found on 10 of the 13 measures for the class 416 group. Table 6 summarizes data of relevance to the ten measures. For each measure, mean values per student in each group are presented in columns one and two. Column three displays percent improvements of the class 416 group over the class 407 group for each measure. The measures are ranked in terms of percent improvement, which ranged from a high of 84 percent to a low of 17 percent for the ten measures. The overall average improvement was 41 percent. The fourth column presents approximate probabilities that the performance improvements could have resulted from chance factors.

No significant differences in performance between the two groups were found for three of the 13 measures. Table 7 summarizes data of relevance to the three measures. In the table, percent change values are given, because not all changes reflected improvements as a result of training in the device.

Mean number of departure errors was slightly less for the group which received training in the device. Mean numbers of enroute errors and approach errors, however, were larger for the trainer (class 416) group. Although differences between groups appear relatively large, particularly in terms of percent change, variability inherent in these measures apparently was sufficiently large to preclude the differences from being statistically significant. It must be concluded, therefore, that differences between groups in terms of numbers of departure, enroute and approach errors were due to chance factors.

TABLE 6. SUMMARY OF PERFORMANCE IMPROVEMENTS RESULTING FROM TRAINER

| Measure | Mean Value, Class 407 Group | Mean Value, Class 416 Group | Percent Improvement | Chance Difference Probability |
|---|---|---|---|---|
| Number of No. 2 Needle Reading Errors | .58 | .09 | 84% | .001 |
| Number of Altimeter Reading Errors | .81 | .30 | 63% | . 01 |
| Number of Wrong Headings | 2.01 | .88 | 56% | .001 |
| Number of Fuel Mgt. Errors | .58 | .36 | 38% | .05 |
| Minutes to Get on Radial | 3.85 | 2.47 | 36% | .01 |
| Percent of Time on Radial | 59.65 | 78.37 | 31% | .001 |
| Number of Missed Calls | 2.38 | 1.65 | 31% | .05 |
| ETAs, No. Minutes Off | 1.52 | 1.08 | 29% | .01 |
| Number of Voice Comm. Errors | 3.77 | 2.86 | 24% | .05 |
| Number of Turn Point Errors | 1.28 | 1.06 | 17% | .05 |

TABLE 7. SUMMARY OF MEASURES SHOWING NO DIFFERENCES BETWEEN GROUPS

| Measure | Mean Value Class 407 Group | Mean Value Class 416 Group | Percent Change |
|---|---|---|---|
| Frequency of Departure Errors | .52 | .42 | 19% |
| Frequency of Enroute Errors | .48 | .75 | 56% |
| Frequency of Approach Errors | .72 | .84 | 17% |

INSTRUCTOR QUESTIONNAIRE RESPONSES. Questionnaires were issued to instructor NFOs and instructor pilots at the conclusion of the data collection period. Content of the questionnaire is contained in Appendix B. Nine of the instructor NFOs and five instructor pilots completed portions of the questionnaire which were applicable to transfer of training from Device 1D23 to airborne point-to-point and airways navigation and communication tasks. Responses of both NFOs and pilots were quite similar. Accordingly, responses from both groups were combined and are summarized below.

To explore the general feeling of instructors regarding the value of training in the device, they were asked to rate how much value they felt training in Device 1D23 had been in preparing students for each T-39 training flight. The rating scale used and the percents of instructors responding to each category are presented in Table 8. A majority of instructors felt that training in the device was of at least moderate value.

A second item was designed to examine instructor views in greater detail. The item consisted of 38 task activities required of students during the T-39 training flights. The activities were clustered under five main topic areas. Instructors were asked to rate how well they felt training in the device prepared students to execute each of the task activites.

TABLE 8. INSTRUCTOR RATINGS OF VALUE OF TRAINING FOR T-39 FLIGHTS

| Flights | Rating Scale Values | | | | |
|---|---|---|---|---|---|
| | Negative | None | Minimal | Moderate | High |
| 1 | 0% | 0% | 15% | 62% | 23% |
| 2 | 0% | 0% | 8% | 69% | 23% |
| 3 | 0% | 0% | 23% | 69% | 8% |

Table 9 summarizes results of the ratings. An "X" in the columns of the table shows median instructor ratings. It is notable that none of the consensus (median) ratings fell within the categories of hurts greatly or hurts some. The performance of nine task activities, however, were rated as having been unaffected by training in the device. The majority of these activities fell under the general topic area of copilot duties; very few task activities associated with copilot duties can be trained in the device. Only two task activities, determining estimated time of arrival and interpreting the Radio Magnetic Indicator were rated as having been helped greatly by training in the device. A much larger number of activities was rated in the category of Helps Some.

TABLE 9. SUMMARY OF TASK ACTIVITY RATINGS, T-39 PHASE

| | Hurts Greatly | Hurts Some | No Effect | Helps Some | Helps Greatly |
|---|---|---|---|---|---|
| PREFLIGHT PLANNING & PREPARATION | | | | | |
| Interpreting airways charts | | | | x | |
| Selecting radio nav aids | | | | x | |
| Preflighting logs | | | x | | |
| Preparing flight plans | | | x | | |
| MEASURING AND COMPUTING | | | | | |
| Determining TAS | | | | x | |
| Determining ground speed | | | | x | |
| Determining ETA | | | | | x |
| Determining wind direction/velocity | | | | x | |
| Determining drift angle | | | | x | |

TABLE 9. SUMMARY OF TASK ACTIVITY RATINGS, T-39 PHASE (continued)

| | Hurts Greatly | Hurts Some | No Effect | Helps Some | Helps Greatly |
|---|---|---|---|---|---|
| **NAVIGATING** | | | | | |
| Understanding radials from nav aids | | | | x | |
| Interpreting RMI | | | | | x |
| Correctly applying drift angle | | | | x | |
| Determining headings to fly | | | | x | |
| Departure procedures | | | | x | |
| Enroute procedures | | | | x | |
| Turn point procedures | | | | x | |
| Directing flight in holding pattern | | | | x | |
| Approach procedures | | | | x | |
| Fuel management | | | | x | |
| Filling out logs | | | | x | |
| Communicating with the pilot | | | x | | |
| **COPILOT DUTIES** | | | | | |
| Interpreting flight instruments | | | x | | |
| Interpreting engine instruments | | | x | | |
| Performing checklist items | | | x | | |
| Tuning radios | | | x | | |
| Setting IFF codes | | | | x | |
| Monitoring UHF radios | | | x | | |
| Communicating with the ground | | | x | | |
| Copying clearances | | | | x | |
| **INTEGRATION OF KNOWLEDGE** | | | | | |
| Getting it all together | | | | x | |
| Interpreting instruction | | | | x | |
| Keeping oriented relative to aircraft position | | | | x | |
| Keeping oreinted relative to direction to checkpoints | | | | x | |
| Pacing tasks to "keep ahead of the aircraft" | | | | x | |
| Anticipating what occurs in flight | | | | x | |
| Understanding spatial relationships | | | | x | |
| Identifying incorrect Nav inputs/ solutions | | | | x | |
| Identifying procedural & computation errors | | | | x | |

Instructors also were asked to address the subject of substituting additional trainer time for flight time. They were unanamous in their view that T-39 flights should not be reduced.

Instructors were asked to elaborate upon why they felt additional training in the device should not be substituted for T-39 training. One strong response pattern addressed "the realism of flight" as previously discussed in Section III. Additionally, time pressures associated with jet flight (420 KTAS in the T-39) were cited. A second strong response pattern centered upon the need for voice communications practice in an airborne environment, which includes static and high communication traffic levels. Other factors cited were: opportunity in the T-39 for students to learn actual rather than generalized cockpit procedures; experience the use of actual flight instruments for flight control, engine monitoring and navigation; and practice in departure, enroute, checkpoint, and approach procedures in the context of real-time constraints.

Instructors also were asked to suggest modifications to the trainer or TPs which might make it possible to substitute training in the device for in-flight training in the T-39. The strongest response pattern centered upon modifying radio communications in the device to include static and communications patter more like that found in the in-flight environment. Additional suggestions were: facilitate real-time communication in the device by shortening communication queues; implement improved methods for monitoring, evaluating and correcting student communications; improve the student-to-instructor ratio; replace the digital readouts in the device with analog displays; place greater training emphasis on fuel management; and place greater training emphasis on developing speed in executing airways navigation and communication tasks.

In two separate questions, instructors were asked to separately list elements of training in the device which they felt had the best value or the least value in preparing students for T-39 training flights. Many elements frequently cited as having the best value could be categorized under the heading of hands-on practice in a near real-time environment, with resulting benefits to the students in: radial tracking; point-to-point navigation procedures; enroute, check point and approach procedures; computational speed and accuracy; and making wind corrections. Other elements centered around pacing to keep ahead of the aircraft, understanding and organizing task priorities, and learning to anticipate what would happen next because of an improved understanding of the sequential events required in jet airways navigation.

The factor listed as having least training value was voice communications training. Instructors generally felt that the training was providing benefit to the student in terms of content and format for radio transmissions. However, more realistic (noisy and with traffic) communications training was strongly recommended. A second factor listed by approximately one third of the instructors as having least value was the use of digital readouts in the device. In the T-39, the student is confronted with actual aircraft displays which require different reading and interpretation skills. One instructor also pointed out that in the trainer, the flight is largely paced by the student, not a pilot. In flight, pilots (and the speed of the aircraft) are key pacing factors; some students have experienced difficulty in making the transition.

Finally, instructors were asked to rate the concept of using Device 1D23 to train all students to at least the same, standardized performance levels prior to allowing them to advance to in-flight training in the T-39. Response options were: very undesirable, possibly undesirable, no opinion, possibly desirable, and very desirable. Sixteen percent (two instructor NFOs) rated the concept as at least possibly undesirable. An additional 38 percent rated the concept as possibly desirable, while the remaining 46 percent rated the concept as very desirable. Those rating the concept as very or possibly undesirable indicated that they felt training in the device was of less value in preparing students for T-39 flights than in preparing them for dead reckoning navigation flights. Apparently, therefore, requiring students to demonstrate certain proficiency levels in the device prior to T-39 training would, in their view, amount to an unnecessary exercise with only minimal payoff.

CONCLUSIONS

Based solely upon statistical analysis of flight grades, it would have to be concluded that training in Device 1D23 had no effect upon the proficiency with which students were able to execute point-to-point and airways navigation and communication tasks in an airborne setting. However, as discussed in Section III, it is felt that reliable conclusions regarding the training effectiveness of Device 1D23 cannot be drawn from flight grades alone.

Based upon statistical analysis of supplemental measures of student task performance, it can be concluded that training in Device 1D23 has resulted in numerous improvements in student performance during T-39 training flights. Greatest improvements were found in the following areas: Accuracy with which the number two needle of the RMI is

read, accuracy with which the altimeter is read, headings to be flown, fuel management, and time required to get on radials. Moderate improvements were found for: the percent of time students were able to stay on radials, identifying incoming radio calls, accuracies of ETAs, and voice communication transmissions. A slight improvement also was found in turn point procedures. Overall, performance in the above areas improved by an average of 41 percent.

Three student performance areas showed no statistically reliable change as a result of the introduction of training in Device 1D23. It can be concluded, therefore, that training in the device had no effect upon student performance of departure procedures, enroute procedures or approach procedures.

Task areas for which moderate or no improvement in student performance was observed following training in Device 1D23 can be considered as definitions of areas in which the training effectiveness of the device could be further enhanced.

Instructor opinion also supports the conclusion that training in the device has resulted in improvements in many aspects of point-to-point and airways navigation performance. It was instructor consensus, however, that the training effectiveness of Device 1D23 is greater in preparing students to execute dead reckoning navigation tasks than in training them to execute tasks required in T-39 training flights. Student performance data collected during the study did not allow for a quantitative verification of this consensus view.

It also appears reasonable to conclude that the effectiveness of the device in preparing students for T-39 training flights could be improved if the device simulated noisier and more heavily trafficked radio communications, if student-to-instructor ratios were improved to provide better control over communications and procedures training, and if the devices' automated performance measurement capability was improved to give a better description of student performance. It also appears reasonable to conclude that the effectiveness of the device could be further improved if it were used to establish acceptable levels of student performance before students would be allowed to advance to in-flight training.

# SECTION V

# EFFECTS OF ADDITIONAL TRAINING IN DEVICE 1D23 UPON DEAD RECKONING NAVIGATION

## OBJECTIVE

The objective for this aspect of the study was to determine the impacts of increased training in Device 1D23 upon student dead reckoning navigation task performance as demonstrated during in-flight training in the T-29 or C-114 aircraft.

## CONTEXT

Objectives associated with in-flight dead reckoning navigation training and the content of in-flight training were the same as previously described in Section III, with one exception. The number of dead reckoning training flights had been reduced from five to four. One of the first two flights was graded; both the third and fourth flights were graded.

The trainer was kept available approximately four hours per day. In keeping with standard practices in effect at VT-10 at the time of the study, students were allowed to voluntarily come in for additional training in the device at their own discretion.

## METHOD

Class 421 was selected for use in this aspect of the study. The class was selected because it was available within the timeframe of the study and because instructor NFOs indicated that students in the class were representative of contemporary students at VT-10.

Two groups of 15 students each were selected from class 421. One group was designated the control group and received the standard amount of training in the device. The other group was designated the experimental group and received one additional trainer session.

The groups were balanced on four dimensions. First, each group contained 12 normally matriculating students plus three students who had been rolled back to class 421 from preceeding classes. Second, both groups contained equal numbers of students who were experiencing academic problems, as indicated by low grades in academic subjects. Both groups also were highly similar in terms of FAR and AQT scores. For both groups, FAR stanine scores ranged from

1 through 8, with a mean of 5.1. For the control group, AQT stanine scores ranged from 4 through 9, with a mean of 6.1. For the experimental group, AQT stanine scores ranged from 3 through 9 with a mean of 5.8.

Both groups of students received introductory training in the operation of Device 1D23 (TPs 1 and 2), followed by prescribed training on TPs 3,4,5, and 6. Experimental group students received one additional training session on TP 4. The additional session was administered on the day after prescribed training on TP 6 had been completed for both groups.

TP 4 was selected for the additional training because it was designed to emulate the lead-tracker navigator structure of the dead reckoning training flights. From a Thorndikeian viewpoint, transfer of training is maximized when elements of training tasks and transfer tasks are identical. In this context, TP 4 appear to offer the best opportunity within the constraints of the study to determine whether additional training in the device would have any in-flight payoff for dead reckoning tasks. A sample of instructor NFOs also agreed that TP 4 offered the highest potential for payoff.

Each dead reckoning training flight consisted of approximately equal numbers of students from the experimental and control groups. This was done in part so that students in both groups would be graded and otherwise evaluated by the same instructor NFOs. Instructors were not told which students were in each group, although they were aware that some of the students had received additional training. It also was done to equate in-flight environmental factors for both groups.

Students in both groups were graded after each flight using standardized Aviation Training Forms and grading criteria. The four point scale previously described in Section III was used to determine a grade for each performance element which was itemized in the Aviation Training Form and which was applicable to the student's requirements during the flight. An overall flight grade was computed for each student in both groups for each flight. This was done by averaging numerical grades across all performance elements.

Following each flight, students in both groups were required to complete a student questionnaire, which actually was a self evaluation form. It was intended to allow each student to express an overall perception of his performance on the flight and a projection of his performance on the next flight. The form also allowed each student to express levels of confidence he felt in executing selected

tasks. Content of the student questionnaire is contained in Appendix D.

Following each flight, instructors were required to complete a student critique form. The form was designed to supplement normal in-flight grades by requiring instructors to express their overall perceptions of student performance and to list the occurrence of selected student behaviors. Content of the student critique form also is contained in Appendix D.

Flight grades and student and instructor overall ratings of student performance were statistically analyzed. Multiple discriminant analysis was used to compare the experimental and control groups on a composite set of measures consisting of: flight grades for the first graded flight, the third flight, and the fourth flight; student self ratings of performance on each flight; student self ratings of anticipated performance on the next flight; instructor ratings of student performance on each flight; and instructor ratings of anticipated student performance on the next flight. Factorial analysis of variance also was used to compare the experimental and control groups separately on flight grades and performance ratings.

Other data developed from the content of student post-flight questionnaires and instructor critique forms were separately analyzed to compare experimental and control groups.

## RESULTS

An examination of records of students voluntarily seeking extra training in the device during free hours showed that approximately equal numbers of students in each group had come in for voluntary extra training. Accordingly, this factor should not have differentially affected group performance.

None of the statistical tests showed any significant differences between the experimental and control groups. It can be reasonably concluded, therefore, that any minor variations between groups were due to chance factors rather than to effects of the additional training in Device 1D23.

Results of the statistical analyses were confirmed by instructor comments. In interviews conducted during and after in-flight training, a sample of instructor NFOs indicated that, on the basis of their observations of student performance, they were unable to identify which students had received additional training in the device.

In a different vein, it was found that student self-ratings of performance averaged approximately one scale unit higher for both groups than the same ratings made by instructors. The difference was statistically significant at the .01 level.

## CONCLUSION

Based upon results of the statistical analyses and upon instructor comments, it can be reasonably concluded that one additional training exposure to TP 4 had no effect upon student in-flight performance of dead reckoning navigation tasks.

# SECTION VI

# EFFECTS OF ADDITIONAL TRAINING IN DEVICE 1D23 UPON AIRWAYS NAVIGATION

## OBJECTIVE

The objective for this aspect of the study was to determine the impacts of increased training in Device 1D23 upon student airways navigation and communication task performance as demonstrated during in-flight training in the T-39 aircraft.

## CONTEXT

Airways navigation and communication training in Device 1D23 and in the T-39 aircraft were the same as previously described in Section IV, with two exceptions. A new training problem (TP 12) was developed by VT-10 personnel to provide expanded training in the device in point-to-point navigation. The new TP was added to the pre-T-39 trainer syllabus. Additionally, the first T-39 flight was changed from a point-to-point navigation flight to an airways navigation flight, thus making all three T-39 flights airways training flights. All three flights were graded.

The trainer was kept available approximately four hours per day. In keeping with standard practices in effect at VT-10 at the time of study, students were allowed to voluntarily come in for additional training in the device at their own discretion.

## METHOD

Class 418 was selected for use in this aspect of the study. The class was selected because it was available within the timeframe of the study and because instructor NFOs indicated that students in the class were representative of contemporary students at VT-10.

Two groups of 14 students each were selected from class 418. One group was designated the control group and received the standard amount of training in the device. The other group was designated the experimental group and received one additional trainer session.

The groups were balanced on four dimensions. First, each group contained 12 normally matriculating students plus two students who had been rolled back to class 418 from preceeding classes. Second, both groups contained equal numbers of students who were experiencing academic

problems. Both groups also were similar in terms of FAR and AQT scores. FAR stanine scores ranged from 1 through 9 for both groups. Mean FAR score for the control group was 5.4, while mean FAR score for the experimental group was 5.5. AQT stanine scores for the control group ranged from 3 through 9, with a mean of 6.6. AQT stanine scores for the experimental group ranged from 4 through 8, with a mean of 6.1.

Both groups of students had received training in the device on TPs 1 through 6, followed by in-flight dead reckoning navigation training. Both groups also received prescribed training on TPs 7, 8, 10, and 12. Experimental group students received one additional training session on TP 7. The additional session was administered on the day after prescribed training on TP 12 had been completed for both groups.

The selection of TP 7 for the additional training of experimental group students was done in concert with a sample of instructor NFOs. It was selected because it was designed to exercise the student in airways navigation and IFR voice communications requirements under nonradar contact conditions. In these respects, task requirements were similar with those required during T-39 airways navigation training flights. Accordingly, TP 7 appeared to offer the best opportunity within the constraints of the study to determine whether additional training in the device would have any in-flight payoff for airways navigation and communication tasks.

Each T-39 training flight contained students from the two groups. In this way, students in both groups were graded and otherwise evaluated by the same instructor NFOs and pilots. Instructors were not told which students were in each group, although they were aware that some of the students had received additional training. Including students from both groups in each flight also equated in-flight environmental factors for both groups.

While in flight, the performance of each student was evaluated by instructors using the supplementary performance evaluation forms previously described in Section IV.

Students in both groups were graded after each flight using standardized Aviation Training Forms and grading criteria. The four point scale, previously described in Section III, was used to determine a grade for each performance element which was itemized in the Aviation Training Form and which was applicable to the student's requirements during the flight. An overall flight grade was computed for each student in both groups for each flight. This was done by averaging numerical grades across all performance elements.

Following each flight, students in both groups were required to complete the student questionnaire described in Appendix D. Following each flight, instructors were required to complete a student critique form,which also is described in Appendix D. Flight grades, student and instructor overall ratings of student performance, and supplemental performance data were statistically analyzed. Multiple discriminant analysis was used to compare the experimental and control groups on a composite set of measures consisting of: flight grades for each flight; student-self ratings of performance on each flight; student-self ratings of anticipated performance on the next flight; instructor ratings of student performance on each flight; and instructor ratings of anticipated student performance on each flight. Factorial analysis of variance also was used to compare the experimental and control groups separately on flight grades and performance ratings.

Multiple discriminant analysis also was used to compare the two groups on a composite set of 13 measures derived from the supplemental performance evaluations. Factorial analysis of variance also was used to separately compare the two groups on each of the 13 measures.

Other data developed from the content of student post-flight questionnaires and instructor critique forms were separately analyzed to compare experimental and control groups.

RESULTS

An examination of records of voluntary extra training in the device during the time when class 418 was receiving pre-T-39 training showed that approximately equal numbers of students in each group had come in for voluntary extra training. Accordingly, this factor should not have differentially affected in-flight performance of the two groups.

None of the statistical tests showed any significant differences between the experimental and control groups. It can be reasonably concluded, therefore, that minor variations between groups were due to chance factors rather than to effects of the additional training in Device 1D23.

In a different vein, it was again found that student self-ratings of performance were generally higher than ratings by instructors. The trend was different, however, than that found for dead reckoning flights. Following the

first two airways flights, students rated their performance approximately one half a scale unit higher than did instructors. These differences were statistically significant at the .01 level. Following the third airways flight, however, student and instructor perceptions of overall student performance appear to have coincided, because ratings by instructors and students were statistically comparable following the third flight.

## CONCLUSION

Based upon results of the statistical analyses it can be reasonably concluded that one additional training exposure to TP 7 had no effect upon student in-flight performance of airways navigation and communication tasks. This conclusion is supported by instructor comments.

# SECTION VII

# EVALUATION OF SELECTED DEVICE DESIGN FEATURES

## INTRODUCTION

An important element of any training effectiveness evaluation is the development of design feedback information. The feedback should be of the type which will be of value to design teams in specifying and developing similar training devices in the future. Accordingly, design feedback information should include descriptions of features which fell short of expectations, along with explanatory information regarding why they may have fallen short. This type of feedback identifies potential pitfalls to be avoided in future designs. Design feedback information also should identify features which appeared to meet expectations, because such information provides positive guidance for future designs. The first type of design feedback is much easier to provide than is the second.

A device as large, complex, and multi-faceted as Device 1D23 incorporates a great number of design features. Simply identifying a comprehensive set of all features could be a major undertaking. Objectively evaluating each feature would require even greater effort which, ideally, should involve the development of criteria of acceptibility and a determination of whether each feature (or selected combinations of features) met criterion. The criteria of acceptibility should be based not only upon desired levels of performance in the user environment, but also upon any cost-effectiveness tradeoffs which may have been made during the specification and development of the device. The advantage of identifying and objectively evaluating each feature is that a comprehensive, unified body of design feedback information can be generated. A disadvantage is the amount of resources required to generate the information.

Selected design feedback can be generated in a much more parsimonious manner by addressing features which, through use, have surfaced as being notably good or notably poor. Four problems, however, are inherent in this approach.

A primary problem is that it is possible to overlook notable design features. This can occur because a comprehensive set of all features is not used to provide guidance. It also can occur because features which work quite well are apt to become inconspicuous and taken for granted.

A second problem is that uniform criteria for evaluating design features may not be applied. It is particularly likely that cost-effectiveness tradeoff factors may not receive formal attention.

A third problem is that it is possible for resulting design feedback information to appear more negative than might actually be the case. This follows since it is much easier to identify design features which have been problematic than those which have not. Consequently, resulting design feedback may be off balance.

Finally, the more parsimonious approach places an additional burden upon teams designing future training devices. This results since, essentially, no design feedback may be provided for "low profile" features which may have functioned quite acceptably. The burden of identifying such features is placed upon members of the design team.

Problems inherent in a more parsimonious approach, however, are offset to some degree by one very practical factor. An advantage of the approach is the enhanced likelihood that at least some design feedback can be provided within the constraints of resources which are available for generating the feedback. In the present study, design feedback information was developed only for selected device design features because of resource constraints. Problems inherent in the parsimonious approach, therefore, are reflected in the design feedback which is presented in this section. Specific procedures for developing the information are presented below.

METHOD

Numerous conversations were held with instructor NFOs, Training Device Operators ( TDs ) and device maintenance personnel throughout the planning and execution phases of the study. The conversational interviews were supplemented by direct observations of device utilization. The observations frequently involved "show me what you mean by that" demonstrations of relevance to various design features. More limited conversational interviews also were held with students who were receiving training in the device. Extensive notes were taken during and after the interviews.

Based upon preliminary interviews, two device evaluation questionnaires were developed. They were developed to provide a structured context within which instructors and students could express comments regarding significant features of the device. Content of the questionnaire which was administered to instructor NFOs is contained in

Appendix A. Only instructors who were qualified to administer training in the device completed the questionnaire. Accordingly, questionnaire responses were obtained from 11 instructors. Content of the questionnaire which was administered to students is shown in Appendix E. The questionnaire was administered to students in class 418 immediately following their inflight training in the T-39 aircraft. The questionnaire also was administered to students in class 422 immediately following their inflight training in dead reckoning navigation (T-29 and C-114 aircraft). A total of 57 students completed questionnaires.

Questionnaire responses were combined with content of the notes taken throughout the planning and execution of the study. The resulting information was then organized into main topic areas. The resulting information is presented below.

## OVERALL DESIGN ACCEPTANCE

Device 1D23 was very well received by instructors, students, Training Device Operators (TDOs) and maintainers. General praise for the device involved both physical design features and the ability of the device to provide meaningful learning experiences. In these respects, it would appear that the device reflects a general design philosophy which should have meaningful utility in the design of other multi-station trainers.

## FACILITY DESIGN

Colors, sound levels, ventilation and illumination were found to be pleasant, comfortable, and well liked. Overall walk-around accessibility to operator consoles, student stations, computers, input-output devices and storage files were quite acceptable. Some student queueing was observed at the performance measurement line printer following training and at the door to the facility during entry and exit of classes. Both types of gueues were transient, however.

## MAINTAINABILITY

The device was quite new at the time the present study was conducted. At that time, however, maintenance of the device appeared to be straightforward and well in hand. Maintenance documentation and maintainer training appeared to have been adequate.

Access to the computers was found to be quite acceptable. Accessibility was one of the factors which facilitated program loading and computer maintenance. Similarly, all

console control-display units were readily accessible for maintenance.

The only major maintenance problem which surfaced during the timeframe of the study involved access to logic circuitry at the front (nearest the wall) of each student station. Access was gained through a hatch on top of the front portion of student stations, and required maintainers to stand on the sides of the stations and lean over and down into the logic circuitry areas. Using the sides of student stations as foot holds appeared less than desirable from a structural standpoint. Additionally, the required procedure appeared to pose a safety problem for maintainers.

Because of low ceiling height in one area of the trainer room, it was impossible to gain access (using the leaning procedure described above) to one of the logic circuit areas of one of the student stations. When the station experiences a malfunction of certain circuitry, it is likely that it will remain in a down state for quite a while.

Maintainability of other elements of the trainer appeared to pose no special problems. In fact, several maintainers indicated that, by and large, maintenance of the device was more straightforward than they had experienced on other simulators and trainers of similar size and complexity.

## SOFTWARE DOCUMENTATION

Programming changes to TPs and creating new TPs involved straightforward programming procedures. Documentation of procedures for changing or creating TP software, in combination with instructor training, appeared to have been sufficient.

Operating system software, however, did not appear to have been adequately documented. Many changes which were felt to be desirable with respect to the operation of the trainer could not be made by Navy personnel. This resulted because documentation which accompanied the device did not describe the system software in sufficient detail.

Other documentation and user training on device operation and maintenance appeared to have been adequate in most cases.

## INSTRUCTOR AND OPERATOR CONSOLES

Instructor and TDO consoles were found to be well organized and well accepted. Chairs which were provided were very comfortable. CRT displays were "flicker free".

Alphanumerics and symbology were legible under the ambient illumination levels in the trainer room. The layout of console keyboards was found to be quite workable by instructors and TDOs. Instructors did express a desire, however, for a switch to deactivate their microphones. Presently, their microphones are always hot, and accidental communication to students is possible. To avoid this, microphones had to be unplugged when not being intentionally used. Additionally, longer microphone cords were desired by several instructors in order to allow them to walk around and observe students while still being able to use the intercom systems.

Information display modes which could be selected for on-line use at instructor and TDO consoles were found to be generally very usable. Instructors made a number of recommendations, however, for enhancing displayed information, simplifying control operations, and enhancing the training utility of the device. The recommendations, summarized below, primarily involved software design. Many appear to have generality to other multi-station training devices.

Uniform capability for both group and individual student station control was highly recommended. Effecting group changes by changing values for individual stations frequently can require hundreds of keyboard entries, which take time and raise the likelihood of a data entry error. Presently, some control functions, such as restarting stations, can be accomplished only for units of 20 stations. Individual restart capability would be very useful for allowing individual students to start over. A group takeoff permissive command capability would be desirable to complement the present individual takeoff permissive capability. Similarly, a group ability to make changes in programmed system values, such as winds and system malfunctions, also was desired.

The on-line inspect and change mode was found to be quite valuable for entering or overriding factors such as atmospheric data, malfunctions, and annunciator messages. Instructors felt that the on-line ability to change navigation aids should have been included in the mode. Again, both group and individual student station control was desired for this mode.

The inclusion of an on-line capability to segregate individual student stations from elements of the systems' software would have been valuable. Student stations which were not used for training had to be brought on line to provide for shifting a student to another station if his malfunctioned or to have a station ready for a student to use to independently practice navigation tasks. This was necessary because stations which were to be active had to be designated during system initialization. It was not possible, therefore, to

activate a station after a TP had begun without stopping training, reinitializing , and starting the TP from the beginning.

The presence of unused but activated stations which were not segregated from stations being used had several effects. The graphic display of student positions on console CRT displays was automatically centered based upon an average weighting of the geographic positions of all activated student stations. Those which were active but which were still "on the ground" resulted in a biased centering of the graphic display. Occasionally, students would "fly off the display" because of the biased centering. As a result, the use of manual centering procedures frequently was required.

When students came in for extra unstructured training, while formal training was ongoing, it was necessary to execute a tedious procedure to free a station from the TP which was being used. The procedure involved getting the station airborne, entering a short ETA, allowing the ETA to expire, unfreezing the station, repositioning it onto the next leg, and repeating the procedure until all legs had been accounted for. The repositioning procedure also was slow and tedious. It would have been far more desirable simply to designate an active station to be segregated from the display centering and performance measurement software.

Finally, active stations which were not being used were scored by the device's automated performance measurement system as having made no errors. The contribution of this erroneous data to student performance measurement is discussed more fully in a subsequent section. Again, however, it would have been highly desirable simply to designate an active station to be segregated from the performance measurement software.

The graphic display of student station positions relative to the course which was to be flown was felt to be quite valuable, particularly for monitoring overall group performance and identifying students who were not adhering to the flight plan. Several improvements in the display were suggested, however. Small lines showing the direction of the velocity vector of each station could be displayed. The vectors proved to be of considerable value in determining whether, for example, a station which was off course was converging on or diverging from the course. It was recommended that a simple control action to produce vectors for all stations on any of the CRT displays would be quite desirable. Additionally, it was suggested that vectors for all stations be displayed when the SACS (specific aircraft submode) mode was selected. The SACS mode was used to obtain a display of selected performance data for a designated student station.

On the graphics display, up to 20 pips were displayed simultaneously, one for each activated student station. No identification was displayed regarding which pip was associated with which student station. Making the identification required the instructors to execute a search routine using the SACS mode. With this mode, a special "S" symbol appeared over the pip which had been designated by entry of a station number. Up to 20 SACS searches were required to identify a particular pip. An improved means for identifying pips would be highly desirable.

The special "S" symbol used with the SACS mode was found to be quite useful. It was recommended that the symbol appear over the pip of a student station when instructors call the station using the intercom system. Additionally, it was recommended that the SACS selected performance data be displayed for the station being addressed. Additionally, it was recommended that just the symbol be displayed on TDO consoles during communications between TDOs and students. Presently, neither the symbol nor the SACS information is displayed automatically during communications.

The out-of-tolerance (AOTS) display mode was found to have little practical value. The mode could either automatically or upon command display selected performance data for stations which were outside of programmed tolerance limits. One problem with using the mode was that, typically, several students would be out-of-tolerance simultaneously. The ambiguity problem of which pip represented which station, as discussed above, rendered the mode of little value. Additionally, more expanded performance data could be obtained through the SACS mode.

The addition of an auditory or visual signal to alert instructors that students were attempting to communicate with them over the intercom also was recommended.

Finally, software which was designed to freeze a student station if it exceeded programmed limits and alert the instructor of the freeze was circumvented. It was found, particularly during early TPs, that numerous student stations were being simultaneously frozen. Because of the student-to-instructor ratios which were common, instructors could not attend rapidly enough to all stations. Accordingly, the stations were simply unfrozen and allowed to resume navigation. Additionally, instructors developed the viewpoint that it was not desirable to freeze stations. Rather, it was better to walk over to an out-of-tolerance station and work with the student in real time to identify and resolve his navigational errors.

STUDENT STATIONS

Student stations were generally well received by both students and instructors. The total volume of each station was adequate to accommodate students without producing claustrophobic responses. However, the relatively small size of the stations made it difficult for instructors to see student logs and charts to diagnose learning problems. Arrangements of navigation, communication and computer entry controls and displays appeared to be orderly and logically organized. All controls and displays were adequately marked and labelled.

Students and instructors were asked to rate the relative difficulty which students experienced in acclimating to several aspects of the student stations. Percents of students and instructors who responded to each difficulty category are summarized in table 10 for four aspects of the student stations.

TABLE 10. ESTIMATES OF STUDENT DIFFICULTY IN ACCLIMATING TO STUDENT STATION

| | Levels of Difficulty | | | |
|---|---|---|---|---|
| | None | Little | Moderate | High |
| Interpreting Digital Readout Displays | 58%* (33%)** | 30% (56%) | 7% (11%) | 5% ( 0%) |
| Using Keyboards for Data Inputs | 30% (11%) | 49% (34%) | 16% (44%) | 5% (11%) |
| Learning Requirements and Procedures for Control of Trainer | 17% ( 0%) | 46% (56%) | 32% (11%) | 5% (33%) |
| Identifying Uses of Cockpit Functional Areas | 23% ( 0%) | 59% (33%) | 13% (56%) | 5% (11%) |

* Percents of Students
** Percents of Instructors

For all four categories, instructors tended to indicate that students experienced slightly higher difficulty levels than was indicated by students. In no case, however, did a majority of either students or instructors indicate that high difficulty was experienced.

Student stations incorporated many light emitting diode (LED) alphanumeric readouts for aircraft parameters, annunciator messages, and computer generated data. The readouts were sufficiently legible, although circuits within the displays were visible. Learning to read and interpret digitally displayed data did not appear to pose a problem. In questionnaire responses, numerous students indicated that the digital readouts were one of the aspects which they liked best about the student stations. However, many instructors and students also indicated a preference for broader use of analog displays, particularly for altitude and time displays. Many students expressed favorable attitudes toward analog displays (attitude and RMI) which were incorporated into student stations. A number of students and instructors also indicated a need for the addition of a capability to display the last ETA entered into the computer by a student. Entry of correct ETAs was critical to the student's achieving a high score from the trainer's automated performance measurement system; students frequently forgot the value of the ETA which they last entered.

Using keyboards for data input apparently posed a somewhat greater difficulty for students, particularly during early training problems. Instructors indicated that three types of data input errors were common. The most frequent was incorrect data entry. The second was incorrect formatting of data which was entered. Finally, students occasionally entered correct data into the wrong entry register. It would appear desirable, therefore, to strengthen training in the use of keyboard entry devices prior to the student's using the device to receive navigation and communication training.

Learning the uses of each functional area of the student stations and learning requirements and procedures for controlling the trainer were rated by students and instructors as being somehwat more difficult. Again, additional familiarization training would appear to be desirable.

In the training problems, as they were originally designed, an annunciator panel in each student station was used to display cues to students, interrogate students, and display knowledge of results feedback. In practice, it was found that the annunciator messages were disruptive to student tasks. Accordingly, the use of the annunciator panel was greatly reduced. Additionally, both instructors and students complained about an auditory tone signal which occurred when a message was removed from the annunciator. The tone provided practically no meaningful information, aside from alerting the student that he may have missed a message, the content of which was unidentified.

Students made numerous comments regarding what might be termed classic human factors design aspects of the student stations. More frequently occurring comments are summarized below.

Although the work surface was larger than any such surface which might be found in two-place aircraft, students felt the surface was too small for the amount of paper work required in navigation, and especially in dead reckoning navigation. It is unlikely that the size of the work surface interfered meaningfully with learning.

Storage space was felt to be less than adequate for the amount of materials which needed to be stored, such as charts and publications.

Illumination levels in certain student stations were felt to be low. This was compounded by the fact that the gooseneck lamps in the stations did not appear to provide meaningful levels of additional illumination.

Some students felt that side consoles were lower than they should be, making it somewhat awkward to reach controls located on the panels.

The headset and communications foot pedal switch received considerable comment. The headsets were found to be uncomfortable by many students. Additionally, the plug for the student's headset was located on the wrong side of the station. As a result, the cord draped across the student's lap and occasionally dragged across the working surface. The foot pedal used to key the microphone could not be easily reached by short students. Other students experienced difficulty by accidentally activating the switch.

Seats used in student stations were the subject of considerable comment. The seats were found to be very uncomfortable after relatively short periods of sitting. Since some TPs required several hours of sitting, the problem became pronounced. Additionally, forward seat travel appeared to be less than necessary, particularly in relation to the small working surface. This required students to lean forward more than should have been necessary to perform tasks such as plotting and measuring. When the seats were at their full aft travel, wheels on the seats ran over the facility carpeting. Ruts in the carpeting were beginning to appear after the trainer had been in use less than six months. Finally, the plastic material used to cover the seats caused considerable perspiration.

## COMMUNICATIONS SYSTEM

It was agreed by both students and instructors that communications training which could be accomplished in the device was of value for learning the content and format of radio communications. Results obtained in the training effectiveness evaluation of the device confirmed their view (see table 6). Both students and instructors also felt that the effectiveness of the device for communications training might be enhanced if simulations of radio communications were more realistic. Presently, the simulated communications channels are very clear and of good fidelity. It was strongly felt that the progressive addition of static, weak signals, and background communications traffic might result in even better transfer of communication training. Similar comments were made regarding the simulation of navigation radio reception.

Device software was designed to preclude the capability for a student to reestablish communications to a station with which he already had communicated. If a student made an error during the first communication with the station, he was unable to communicate again to correct the error if he had, in the meantime, switched to a different frequency. This feature was found to be undesirable and unrealistic.

To communicate with instructors or TDOs, students activated a foot switch. This procedure placed their communication request in a queue with other request backlogs. Communication with students was then handled individually on a first come first serve basis. Both students and instructors suggested the addition of some form of feedback to the student to indicate that his request was in a queue. The importance of such feedback takes on particular meaning in light of the fact that, during peak communication periods, students frequently had to wait for up to 15 minutes in queue.

Several suggestions were made for reducing communication queues. One was to simulate ATIS (Airport Taped Information Service). A second recommendation was to designate specific TDOs to handle specific communication functions such as: clearance delivery, ground control, departure control, tower and center. Presently, each TDO handles all communications functions. Instructors also felt that the quality of transmissions by TDOs could be improved through functional allocation.

## AUTOMATED PERFORMANCE MEASUREMENT CAPABILITY

Device 1D23 incorporated an automated student performance measurement system. Experience with the system showed, however, that it fully satisfied neither student nor instructor needs

for straightforward, highly usable feedback on student performance and progress. Valid, objective measurement of performance, however, is essential for assessing student progress, diagnosing learning problems, and determining when acceptable, criterion-based levels of performance have been achieved.

Instructors were asked to rate the utility of the present measurement system output for reconstructing flights. Sixty-four percent rated the value of the output as being moderate to high for reconstructing flights. Several instructors pointed out, however, that logs and charts must be used in conjunction with the printout. They further pointed out that a complete post-mission debriefing and reconstruction could require approximately 10 minutes per student. Generally, therefore, the measurement system output was used by individual students as an aid in reconstructing their own flights.

Instructors also were asked to rate the utility of the measurement system output for evaluating student performance. Forty-five percent rated the output as having minimal or no value. An additional 45 percent rated the output as having only moderate value. The need for improvements to the measurement system takes on added perspective when it is considered that 64 percent of instructor NFOs rated as very desirable the use of the device to train students to the same, quantifiable levels of performance prior to allowing them to progress to in-flight dead reckoning navigation training. Fifty percent rated as very desirable the same use of the device prior to in-flight airways navigation and communication training.

Several elements of the measurement system's operation and output were found to contribute to the system's evaluation by instructors. Some measures were of little practical value. Other measures were overly influenced by estimated time of arrival errors. Performance measurement was not independent for each leg, resulting in cascading effects. Some measures were not made if students failed to input necessary information from student stations. Measurement of communication errors by TDOs appeared to be less standardized than would be ideally desired. Measures of relative student performance were degraded by the fact that activated but unused student stations were graded as perfect, having never taken off and, therefore, having never made errors. Finally, the output contained some quantitative indices which were understood by neither instructors nor students. Documentation provided with the device did not define these quantitative indices.

The automated performance measurement system was used during the timeframe of the present study to determine whether students had achieved criterion performance. During TP 12, students were required to achieve a minimum grade of 3.2, but the grade was based solely upon a single measure, circular error distance from turn points at ETA expiration.

In November of 1973 it was learned that plans had been made to use Device 1D23 in a proficiency advancement role. The plan called for students to achieve certain minimum standards of performance in the device before they would be allowed to advance to in-flight airways training. It was planned, however, to utilize additional instructors and evaluate student performance using Aviation Training Forms and in-flight performance criteria, rather than the automated performance measurement system.

STAFFING LEVELS

Determining personnel requirements involves procedures which, by nature, are not overly objective and quantitative. The following information is presented to provide guidelines for estimating manning requirements in similar devices to be designed in future timeframes. The information is quite limited and reflects, perhaps as much as anything, a shortage of instructional personnel at VT-10 during the timeframe when the study was conducted. Subsequent to the study, the shortage was relieved to some extent. It would seem reasonable, therefore, to supplement the information presented below with more current data regarding acceptable staffing levels.

During the study, student-to-instructor ratios averaged between 12 and 16 to one, depending upon the phase of training being administered in the device. Instructors were asked how often the student-to-instructor ratio seemed too large for an individual instructor to be able to effectively instruct. Results are shown in table 11, which presents the percent of instructors who responded to each frequency category for the three training phases shown. It is apparent from the table that the prevailing student-to-instructor ratios seemed frequently or always too large to a considerable majority of instructors.

As discussed previously under the subject of the communication system, student to TDO ratios also appeared too high, at least for peak communications periods. Student to TDO ratios averaged between six and eight to one. Additional TDO capabilities for peak communications periods may have been desirable.

The number of maintenance personnel appeared to be adequate at the time the study was conducted.

TABLE 11. SUMMARY OF INSTRUCTOR EVALUATION OF STUDENT TO INSTRUCTOR RATIOS

| Training Phases | Relative Frequency with which Student-to-Instructor Ratios Seemed too Large | | | |
|---|---|---|---|---|
| | Never | Occasionally | Frequently | Always |
| Pre-T-29 | 0% | 12% | 38% | 50% |
| Pre-T-39 | 14% | 14% | 29% | 43% |
| Pre-F-9 | 33% | 0% | 34% | 33% |

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# APPENDIX A

## SYNOPSIS OF PREPROGRAMMED TRAINING PROBLEMS

Contents of Training Problems (TPs) 1 through 12 are briefly described below. The descriptions are based primarily upon the content of the 1D23 Briefing Guide (Ref 2). The guide was published in June 1973.

The descriptions which follow generally reflect content of the TPs during the timeframe (January through July 1973) when data were collected for the study. However, minor adjustments to TPs were frequent. For example, grading criteria for various TPs underwent frequent changes, as did numbers and types of navigation aids which were made available to students. Also, equipment failures which were either programmed or manually inserted into the system varied from time to time. The descriptions which follow, therefore, are best interpreted as reflecting the major thrust of each TP.

TRAINING PROBLEMS 1 AND 2, DEVICE INTRODUCTION DESCRIPTION

TPs 1 and 2 provided a highly preprogrammed indoctrination in the operation and capabilities of the trainer. Each student was shown a student station and was talked through a programmed sequence on the use of device controls, performance of instruments and displays, and performance tolerance limits.

TRAINING OBJECTIVE. The objective of these problems was to familiarize the trainee with the controls, indicators, and procedures to be used in order to practice navigation tasks in the device.

FLIGHT INFORMATION. The following flight information was used:

Charts. Primary: Mississippi River Central
Secondary: ONC H-24

Route. NAS Pensacola, Saufley VOR, Picayune VORTAC, Esler VOR, Laurel VOR, Saufley VOR, NAS Pensacola

Temperature Rise. A temperature rise of +3 degrees was used.

Preparation. Students were required to have preflight completed, including log and chart, prior to entering the trainer room.

NAVIGATION AIDS AVAILABLE. A total of 23 navigation aids was available, including TACAN, ADF, VOR, and VORTAC.

GRADING CRITERIA. Grading criteria were not applicable to TPs 1 and 2.

EQUIPMENT USED. Students received a two hour lecture prior to TPs 1 and 2 to familiarize them with the various aspects of the device. All capabilities of the device were then demonstrated.

PROCEDURAL NOTES. For these TPs, students needed only to follow instructions provided by the instructor on how to operate the device and interpret displayed feedback.

NAVIGATION TOOLS. The following navigation tools were required: dividers, CR computer, plotter, preflighted chart and log, spare logs, IFR supplement, low altitude airways chart, low altitude approach plates, paper, and pencil.

TRAINING PROBLEM 3, DR NAVIGATION

DESCRIPTION. TP 3 was "flown" in an approximated E-2A type aircraft. Aircraft cruise altitude and airspeed were controlled by the training device. One altitude change occurred during the flight. TACAN DME was failed part way through the mission to force the student to use multiple LOP (line of position) position fixing.

TP 3 was designed to exercise the trainee in the fundamentals of dead reckoning navigation; use of the plotter, divider, hand computer, charts; and basic procedures to solve for position of the aircraft, direction to destination, and time of arrival.

Students were responsible for the calculation and input of ETAs, winds, and positions for automated performance evaluation. They also were responsible for directing the flight over the prescribed route.

Voice communications with the ground included proper use of current procedures for clearance delivery, ground control, tower, departure control, and VFR position reports to a Flight Service Station.

TRAINING OBJECTIVES. Upon completion of TP 3, it was intended that the student would be able to:

1. Plot TACAN and multiple LOP fixes on charts.
2. Operate keyboard to enter fix information.
3. Operate UHF radio controls.
4. Give VRF position report.
5. Communicate correctly with ground, tower, departure, and Flight Service Station using proper jargon and format.

6. Plot dead reckoning courses.
7. Utilize plotter, dividers and CR computer,
8. Dead reckon ahead using real time information.
9. Complete proper entries in a DR in-flight navigation log.
10. Calculate ETAs.
11. Correlate instrument reading and chart plotting.
12. Apply wind and position information to make course corrections.
13. Determine wind by track/groundspeed and airplot methods.
14. Operate TACAN, VOR and UHF ADF equipment.
15. Recognize navaid station passage from cockpit instrument indications.
16. Operate keyboard to enter wind information for grading and navigation updating.
17. Operate keyboard to enter ETAs.

FLIGHT INFORMATION. Same as TP 1.

NAVIGATION AIDS AVAILABLE. Same as TP 1.

GRADING CRITERIA. The following criteria were programmed into the device's automated performance evaluation system:

| Descriptions | Grade | Limits |
|---|---|---|
| Positions | 4 | 0-2 NM |
| | 3 | 2-4 NM |
| | 2 | 4-6 NM |
| | 1 | > 6 NM |
| Winds | 4 | $15^0$ and 5 KTS |
| | 3 | $25^0$ and 5 KTS |
| | 2 | $30^0$ and 12 KTS |
| | 1 | $>30^0$ or 12 KTS |
| Turn Points | 4 | 0-3 NM |
| | 3 | 3-6 NM |
| | 2 | 6-8 NM |
| | 1 | > 8 NM |

Each position, wind, and turn point was graded individually and then averaged together with all other positions, winds, and turn point inputs to develop an overall performance average (grade) for the student.

EQUIPMENT USED. The following equipments, simulated in the device, were used: TACAN, VOR, UHF ADF, UHF Command Radio, UHF Auxiliary Radio, and IFF.

PROCEDURAL NOTES. The student briefing guide for Device 1D23 and instructor briefings prior to TPs 1 and 2 stressed several points. The points are addressed below.

Turn point circular error was determined by comparing the actual position of the "aircraft" with the actual position of the turn point at the time of ETA expiration, as calculated and entered by the student. The determination and entry of accurate ETAs, therefore, was critical to achieving successful performance. A specific step-by-step procedure was recommended for students to use each time they took a fix. Students were encouraged to continually update their ETAs.

Aircraft flown at VT-1. displayed an indicated outside air temperature. However, the trainer was designed to give true outside air temperature. Students were advised of this difference.

Students also were instructed in special techniques for folding charts so that they would fit on the relatively small working surfaces in the trainee stations.

Because accomplishment of proper voice communications was one of the major objectives of training in Device 1D23, students were given explicit voice procedures to be used. They also were admonished not to expect an immediate response when making a voice report because of high instructor workloads during departure and approach phases.

NAVIGATION TOOLS. Same as TP 1.

TRAINING PROBLEM 4, DR NAVIGATION

DESCRIPTION. TP 4 was flown in an approximated E-2A type aircraft. Aircraft cruise altitude and airspeed were controlled by the training device.

TACAN DME was failed part way through the mission to force the student to use multiple LOP position fixing. The construction and use of an EP (estimated position) also was required.

As in TP 3, the student was responsible for calculating and inputing ETAs, winds, headings, and positions while using basic dead reckoning procedures.

All voice communications with the ground were the responsibility of the student.

TP 4 also was designed to prepare students for the roles they would assume during in-flight dead reckoning training. To do this, students were divided into groups. One student in each group assumed the role of lead navigator while the remaining students assumed the role of tracker. Students took turns acting as lead navigators during the mission.

TRAINING OBJECTIVES. Upon completion of TP 4, it was intended that the student would be able to:

1. Apply corrections, computations and procedures as outlined in the TP 3 objectives.

2. Communicate with all controlling agencies using proper voice procedures.

FLIGHT INFORMATION. The following flight information was used:

<u>Charts</u>. Primary: State of Florida
Secondary: Florida Atlantic Coast Area

<u>Route</u>. NAS Pensacola, Crestview VORTAC, Tallahassee VORTAC, St. Petersburgh VORTAC, Jacksonville VORTAC, NAS Mayport.

<u>Temperature Rise</u>. A temperature rise of +4 degrees was used.

<u>Preparation</u>. Students were required to have preflight completed, including log and chart, prior to entering the trainer room.

NAVIGATION AIDS AVAILABLE. A total of 34 navigation aids was available, including TACAN, ADF, VOR, and VORTAC.

GRADING CRITERIA. Same as TP 3.

EQUIPMENT USED. Same as TP 3.

PROCEDURAL NOTES. Procedures for TP 3 were reviewed. Estimated position and advance and retard construction and use were discussed by instructors.

NAVIGATION TOOLS. Same as TP 1.

TRAINING PROBLEM 5, DR NAVIGATION

DESCRIPTION. TP 5 was flown in an approximated E-2A type aircraft. Aircraft cruise altitude and airspeed were controlled by the training device.

The problem included two airplot phases based on pilot evasive action for weather. It also included failure of TACAN capability, forcing the student to use multiple LOP position fixing. Students also were required to plot three estimated positions using single LOPs, and determine position by using advance and retard techniques.

As in TPs 3 and 4, the student was responsible for the calculation and input of ETAs, winds, headings and positions.

TRAINING OBJECTIVE. Upon completion of TP 5, it was intended that the student would be able to:

1. Apply corrections, computations and procedures as outlined in TP 3 and 4 objectives.

2. Operate UHF controls and make all voice reports required and/or requested.

3. Plot and log estimated positions.

4. Construct and compute an airplot wind while evading weather.

5. Construct and utilize advance and retard LOPs for position determination.

FLIGHT INFORMATION. The following flight information was used:

Charts. Primary: Missippi River Central
Secondary: ONC H-24

Route. NAS Pensacola, Saufley VOR, Baton Rouge VORTAC, Sabine Pass VORTAC, Leeville VORTAC, Saufley VOR, NAS Pensacola.

Temperature Rise. A temperature rise of +6 degrees was used.

Preparation. Students were required to have preflight completed, to include log, chart, and DD-175, prior to entering the trainer room.

NAVIGATION AIDS AVAILABLE. A total of 18 navigation aids was available, including TACAN, ADF, VOR, AND VORTAC.

GRADING CRITERIA. Same as TP 3.

EQUIPMENT USED. Same as TP 3.

PROCEDURAL NOTES. Procedures for TPs 3 and 4 were reviewed. Procedures were reviewed for construction and use of an airplot while evading weather, and use of advance and retard LOPs. Standard instrument departure procedures were discussed during the premission briefing.

NAVIGATION TOOLS. Same as TP 1.

TRAINING PROBLEM 6, DR NAVIGATION

DESCRIPTION. TP 6 was designed as a DR navigation check ride to evaluate student proficiency in all DR navigation procedures. It was flown in an approximated E-2A type aircraft.

Aircraft altitude was controlled by the student. On one leg, the student was given a controlled time of arrival problem. The TP also included a forced diversion to an alternate destination, requiring a change in flight plan. As in all training problems, the student was responsible for all voice communications, and corrections and calculations of ETAs, winds and positions.

TRAINING OBJECTIVES. Upon completion of TP 6, it was intended that the student would be able to:

1. Apply corrections, computations, and procedures as outlined in TP 3.

2. Detect and compensate for equipment malfunctions.

3. Compute and execute a controlled time of arrival problem.

FLIGHT INFORMATION. The following flight information was used:

<u>Charts</u>. Primary: Mississippi River Central
Secondary: ONC H-24

<u>Route</u>. NAS Pensacola, Saufley, N29-37 W92-00, Polk VOR, Jackson VORTAC, Saufley VOR, NAS Pensacola.

NAVIGATION AIDS AVAILABLE. A total of 27 navigation aids was available, including TACAN, ADF, VOR, and VORTAC.

GRADING CRITERIA. Same as TP 3.

EQUIPMENT USED. Same as TP 3.

NAVIGATION TOOLS. Same as TP 3.

PROCEDURAL NOTES. Procedures for TP 5 were reviewed.

NAVIGATION TOOLS. Same as TP 1.

TRAINING PROBLEM 7, LOW-LEVEL AIRWAYS NAVIGATION

DESCRIPTION. TP 7 was designed to exercise the student in "Victor" airways navigation and IFR voice communications requirements under nonradar-contact conditions. It was flown in an approximated E-2A type aircraft. Cruising airspeed was under program control, and required altitude changes were under trainee control.

The student was responsible for all turning point ETAs and for directing the aircraft along the airways using FLIP chart inbound/outbound radials. The student was responsible for fuel management and the use of a jet log. Also, students were responsible for all IFR voice communications, both directed and mandatory.

TRAINING OBJECTIVES. Upon completion of TP 7, it was intended that the student would be able to:

1. Direct the flight over low altitude airways.
2. Demonstrate airways procedures including reporting requirements.
3. Give IFR position reports.
4. Use aircraft systems (VOR/TACAN) to compute ETA.
5. Operate navaids to maintain flight on radials.
6. Operate navaids to navigate point-to-point.
7. Input necessary heading changes to maintain course
8. Operate UHF radio correctly.
9. Communicate using proper jargon and formats.
10. Utilize low altitude FLIP publications (chart, approach plates, IFR supplement).
11. Properly use a jet log.
12. Preflight estimated fuel required and maintain the status of in-flight actual fuel consumption.

FLIGHT INFORMATION. The following flight information was used:

Charts. L-17/18 and L-19/20.

Route. NAS Pensacola, Crestview VORTAC, V-189 Tallahassee, V-225 Key West, initial approach fix HI-VORTAC 07.

Temperature Rise. A temperature rise of +10 degrees was used.

Preparation. Students were required to have preflight completed, including jet log, L-17/18, L-19/20, and DD-175, prior to entering the trainer room. Basic information for the DD-175 was provided to the students.

NAVIGATION AIDS AVAILABLE. A total of 33 navigation aids was available, including TACAN, ADF, VOR, and VORTAC.

GRADING CRITERIA. Same as TP 3.

EQUIPMENT USED. The full system capability of the device was used.

PROCEDURAL NOTES. TP 7 involved airways navigation and communication. The student was required to maintain a desired radial, navigate TACAN point-to-point, communicate on UHF, and manage the fuel. The student had previously been taught the necessary procedures. In the briefing prior to the mission, specific procedures required for radial tracking and point-to-point navigation were reviewed.

For the mission, students were advised to plan turns so as not to overshoot turn points. At a TAS of 320 knots and a heading change greater than 45 degrees, they were advised to lead the turn by about 3 nautical miles. Because leading turns were necessary, students were cautioned regarding entering the next ETA prior to the expiration of a current ETA.

Cruise control data and normal thrust climb data for the E-2A simulation were provided to the students.

NAVIGATION TOOLS. The following navigation tools were required: CR computer, completed jet logs, low altitude airways charts, DD-175, low altitude approach plates, high altitude approach plates, enroute supplement, pencil and paper.

TRAINING PROBLEM 8, HIGH ALTITUDE AIRWAYS NAVIGATION

DESCRIPTION. TP 8 was flown in an approximated F-4J aircraft. Cruising airspeed was under program control; required altitude changes were under student control.

TP 8 was designed to exercise the student in high altitude airways navigation in a radar contact environment. The TP reflected a continuing emphasis on IFR requirements and procedures. Students were required to initiate an in-flight refiling of clearance. This resulted in the need to change preflighted data. Students were responsible for flight direction along airways as initially cleared and to the intersection of a new airway after refiling clearance. Students also were responsible for all IFR voice communications, both directed and mandatory.

TRAINING OBJECTIVES. Upon completion of TP 8, it was intended that students would be able to:

1. Control information sources and operate equipment as outlined in TP 7.

2. Direct the flight over high altitude airways (radial tracking) and navigate using navaid offsets from the airways (point-to-point navigation),

3. Correctly apply airways procedures and voice communications procedures.

4. Use high altitude FLIP publications (charts, approach plates, IFR supplement).

FLIGHT INFORMATION. The following flight information was used:

Charts. H-3/4.

Route. NAS Pensacola, Crestview VORTAC, J-50 McComb VORTAC, Jackson VORTAC, Greenwood VORTAC, Memphis VORTAC, J-39 Crestview VORTAC, initial approach fix NPA (runway 06) NAS Pensacola.

Temperature Rise. A temperature rise of +25 degrees was used.

Preparation. Students were required to have preflight completed, including jet log, H-3/4 and DD-175, prior to entering the trainer room. Basic information for the DD-175 was provided to the students.

NAVIGATION AIDS AVAILABLE. A total of 37 navigation aids was available, including TACAN, ADF, VOR, and VORTAC.

GRADING CRITERIA. Same as TP 3.

EQUIPMENT UTILIZED. The full system capability of the device was used.

PROCEDURAL NOTES. Procedural notes were the same as those for TP 7, except that students were advised to lead turns by 4 nautical miles when a heading change greater than 45 degrees was required.

NAVIGATION TOOLS. The following navigation tools were required: CR computer, completed jet logs, high altitude airways charts, DD-175, high altitude approach plates, enroute supplement, and paper and pencil.

TRAINING PROBLEM 9, OPERATIONAL NAVIGATION MISSION

DESCRIPTION. TP 9 was a simulated bombing mission in an approximated A-6E aircraft. It was designed to exercise the student in the use of advanced navigation systems found in modern aircraft.

TP 9 involved a launch from an aircraft carrier, followed by climb to altitude and departure point using the carrier TACAN. A target time was given to the student prior to departing on the enroute phase. The student exercised control over aircraft speed to make the target time good.

All navigation systems were operational, but radio navaids were limited to the carrier TACAN and one land based alternate.

Upon completion of the target run, the student directed the flight back to the carrier utilizing available navigation systems. The student was given a marshal point after establishing voice communications with the carrier at 40 nautical miles.

The student was responsible for enroute navigation, fuel control, airspeed and altitude control, and proper utilization and validation of navigation systems.

TRAINING OBJECTIVES. Upon completion of TP 9, it was intended that students would be able to execute the following:

1. Utilize navigation systems to check position, maintain course, and meet turn point and target ETAs.

2. Make appropriate voice reports to controlling agencies.

3. Manage fuel and not exceed required minimums.

4. Adjust airspeed to make good ETAs.

FLIGHT INFORMATION. The following flight information was used:

Chart. ONC H-25.

Route. Ship (29-00N, 76-00W), rendezvous point (29-07N, 76-27W), coast in point (30-28N, 81-25W), initial point (28-53N, 82-36W), target (27-53N, 82-34W), coast out point (27-14N, 80-12W), A/H to marshall (28-32N, 76-32W), marshal (carrier TACAN radial and DME), Ship.

Temperature Rise. The navigation computer was used to compute TAS.

Preparation. Students were required to have preflight completed, including attack log and ONC chart, prior to entering the trainer room.

NAVIGATION AIDS AVAILABLE. The Glynco TACAN and the Ship TACAN were available.

GRADING CRITERIA. Same as TP 3, with the addition of a bombing grade, which is defined below.

| Grade | Limits |
|---|---|
| 4 | Bullseye |
| 3 | <1 NM |
| 2 | 1-2 NM |
| 1 | >2 NM |

EQUIPMENT UTILIZED. The full system capability of the device was used.

PROCEDURAL NOTES. This was the first training problem that required students to utilize aircraft navigation systems almost exclusively. Only one TACAN station was used to update the navigation computer. Specific procedures for utilizing the station were given to the students.

NAVIGATION TOOLS. The following navigation tools were required: CR computer, completed attack log, ONC chart, paper and pencil.

TRAINING PROBLEM 10/11, CHECK MISSION

DESCRIPTION. TP 10/11 was flown in an approximated F-4J aircraft with all navigation systems operational. It was a check ride to evaluate student proficiency in all areas of navigation taught at VT-10.

TP 10/11 consisted of two independent problem phases. Phase one (TP 10) was an IFR airways flight and was similar to TP 8 with respect to airways navigation, voice communications, and airways aircraft control. Phase two (TP 11) involved a departure from Patrick AFB to intercept an aircraft carrier. It was similar to the latter part of TP 9.

The two phases were separated so that all students concluded the first phase before any students started the second phase. The interim time between phases was scheduled for flight planning and preflighting of the second phase.

TRAINING OBJECTIVES. Upon completion of TP 10/11, it was intended that the student would be able to:

1. Operate all navigation and communication equipment as outlined in TPs 3 through 9.

2. Utilize all navigation systems to check positions, maintain course, and meet ETAs.

3. Make appropriate voice reports to all controlling agencies.

4. Correctly complete appropriate logs and forms.

5. Manage fuel and understand minimums required.

FLIGHT INFORMATION. The following flight information was used:

Charts. TP 10: H-3/4.
TP 11: ONC H-25.

Routes. TP 10: NAS Pensacola, Crestview VORTAC, J-2 Tallahassee VORTAC, J-20 Orlando VORTAC, Patric AFB initial approach fix (Polaris).

TP 11: Patrick AFB, Sturgeon intersection (28-34N, 78-51W), A/H to Ship (24-46N, 76-26W).

Temperature Rise. The navigation computer was used to compute TAS.

Preparation. Students were required to have preflight completed, including jet log, chart, and DD-175, prior to entering the trainer room for either TP.

NAVIGATION AIDS AVAILABLE. Ten navigation aids were available, including TACAN, ADF, VOR and VORTAC.

GRADING CRITERIA. Same as TP 3.

EQUIPMENT UTILIZED. The full system capability of the device was used.

PROCEDURAL NOTES. The DD-175 did not reflect the route planned because the ship's position was not given prior to TP 11. The DD-175 for TP 11 was discussed during the premission briefing.

NAVIGATION TOOLS. Same as TPs 8 and 9.

TRAINING PROBLEM 12, POINT-TO-POINT NAVIGATION

DESCRIPTION. TP 12 was designed to instruct and test the student in point-to-point navigation. The student had full control of airspeed, altitude and heading. A total of eight points was used. The student was required to score 3.2 or higher (average for all points) prior to advancing to in-flight training in the T-39 aircraft. Each student was given three chances to qualify prior to his being interviewed by the Navigation Branch Officer.

TRAINING OBJECTIVES. Upon completion of TP 12, it was intended that the student would be able to:

1. Operate navaids to navigate point-to-point proficiently (score 3.2 or higher).

2. Calculate and input ETAs for grading purposes.

3. Calculate groundspeed and wind mentally.

FLIGHT INFORMATION. The following flight information was used:

Charts. No charts were needed.

Route. Annunciator messages were used to describe the radial and DME for each point.

Temperature Rise. A temperature rise of +14 degrees was used.

Preparation. No preparation of charts or forms was required.

NAVIGATION AIDS AVAILABLE. A total of 40 navigation aids was available, including TACAN, ADF, VOR, and VORTAC.

GRADING CRITERIA. The following grading system was applied for distance from a point at the expiration of ETA:

| Grade | Limit |
|---|---|
| 4 | <2 NM |
| 3 | 2.1 NM - 4.0 NM |
| 2 | 4.1 NM - 6.0 NM |
| 1 | >6.0 NM |

PROCEDURAL NOTES. Students were required to determine winds mentally. Students were required to calculate an indicated airspeed which would give a true airspeed of 360 knots at 16,000 feet.

Students were advised that ETAs were critical to the computation of their grade. Keesler, Hattiesburg, and Navy Meridian TACANs were utilized. The student was given control of the flight at 500 feet of altitude.

NAVIGATION TOOLS. The following navigation tools were required: CR computer (used only to calculate IAS), paper and pencil.

# APPENDIX B

## CONTENT OF INSTRUCTOR QUESTIONNAIRE

Name ___ ________________ Rank ________________

Please check one: NFO _____ Pilot _____

Indicate the month and year when you began instructing at VT-10: ______________________________

Check the system(s) in which you presently are qualified to instruct. T-29 _____ T-39 _____ 1D23 _____

Over the past two months only, estimate the percentages of your training hops you flew in each of the following aircraft:

T-29 _____% T-39 _____%

At the time when training in Device 1D23 was initiated (December 1972), estimate the percentages of your training hops you flew in each of the following aircraft:

T-29 _____% T-39 _____%

How many student classes have you instructed in Device 1D23? _____

Questionnaire and rating scale items which follow have been organized into three main sections. Please read the brief statement at the beginning of each section. You need complete only those sections which apply to you.

SECTION 1. IMPACTS OF TRAINING IN DEVICE 1D23 UPON STUDENT PERFORMANCE IN THE T-29 FLIGHT STAGE.

You should complete this section only if you were instructing in T-29 aircraft during the period (December 1972-January 1973), when training in Device 1D23 was initiated.

1.1 Overall, how much value do you feel training in Device 1D23 has been in preparing students for T-29 flights? (Place an "x" squarely in one category).

| | | | | |
|---|---|---|---|---|
| | | | | |
| Negative value | No Value | Minimal Value | Moderate Value | High Value |

1.2 The following item is intended to examine the approximate magnitude of any changes in student performance which may have been evident following the introduction of training in Device 1D23. The four current B-series flights are listed below. In the space to the right of each flight, please write the B-series flight on which comparable student performance was typical before the introduction of Device 1D23. For example, if you feel that it used to take through the B-3 flight before students were performing as well as they now are on their B-1 flight, then you would write "B-3" in the space to the right of the B-1 flight. If on the other hand, you feel that performance on present B-1 flights is virtually the same now as it was before Device 1D23 was introduced, then you would write "B-1" in the space to the right of the B-1 flight.

| Presently Observed Performance Levels | Flight on Which Comparable Performance Levels Were Typical Before Device 1D23 |
|---|---|
| B-1 | ______ |
| B-2 | ______ |
| B-3 | ______ |
| B-4 | ______ |

1.3 Using the rating scale on the following page, place "X's" squarely within the ratings which best reflect your feelings about how well training in Device 1D23 prepares students for T-29 training flights.

Several task categories are presented. For each task category, please indicate your feelings about how well training in the simulator prepares students to execute the task category during T-29 training flights.

Your second task is to continue by making separate ratings for each task category.

Simply repeat the above procedure until you have completed all of the ratings. Then complete the questionnaire items on the following pages.

| | Hurts Greatly | Hurts Some | No Effect | Helps Some | Helps Greatly |
|---|---|---|---|---|---|
| PREFLIGHT PLANNING & PREPARATION | | | | | |
| Interpreting charts. . . . . . . . . . . . . . | | | | | |
| Identifying restricted areas . . . . . . . . . | | | | | |
| Plotting courses . . . . . . . . . . . . . . | | | | | |
| Using correct symbology . . . . . . . . . . | | | | | |
| Selecting radio nav aids . . . . . . . . . . | | | | | |
| Preflighting logs. . . . . . . . . . . . . . | | | | | |
| Preparing flight plans . . . . . . . . . . . | | | | | |
| MEASURING AND COMPUTING | | | | | |
| Using CR 2/3 computer . . . . . . . . . . . | | | | | |
| Using plotter & divider. . . . . . . . . . . | | | | | |
| Determining TAS . . . . . . . . . . . . . . | | | | | |
| Determining ground speed . . . . . . . . . . | | | | | |
| Determining ETA . . . . . . . . . . . . . . | | | | | |
| Determining wind direction/velocity. . . . . | | | | | |
| Determining drift angle. . . . . . . . . . . | | | | | |
| NAVIGATING | | | | | |
| Dead reckoning procedures. . . . . . . . . . | | | | | |
| Understanding radials from nav aids. . . . . | | | | | |
| Plotting accurate TACAN fixes. . . . . . . . | | | | | |
| Plotting multiple LOPs . . . . . . . . . . . | | | | | |
| Advancing/retarding LOPs . . . . . . . . . . | | | | | |
| Plotting EPs . . . . . . . . . . . . . . . . | | | | | |
| Applying variation . . . . . . . . . . . . . | | | | | |
| Converting between Mag & true heading. . . . | | | | | |
| Plotting track, no-wind, wind lines . . . . | | | | | |
| Using correct DR symbology . . . . . . . . . | | | | | |
| Dead reckoning ahead . . . . . . . . . . . . | | | | | |
| Correctly applying drift angle . . . . . . . | | | | | |
| Determining headings to fly. . . . . . . . . | | | | | |
| Filling out logs . . . . . . . . . . . . . . | | | | | |
| Communicating with pilot . . . . . . . . . . | | | | | |

| INTEGRATION OF KNOWLEDGE | Hurts Greatly | Hurts Some | No Effect | Helps Some | Helps Greatly |
|---|---|---|---|---|---|
| Getting it all together | | | | | |
| Interpreting instruction. | | | | | |
| Keeping oriented relative to aircraft position | | | | | |
| Keeping oriented relative to direction. to checkpoints | | | | | |
| Pacings tasks to "keep ahead of the aircraft" | | | | | |
| Anticipating what would oocur in. flight | | | | | |
| Understanding spatial relationships | | | | | |
| Identifying incorrect nav. inputs or. solutions | | | | | |
| Identifying procedural and computationsl. errors | | | | | |

1.4 Do you feel that additional training in Device 1D23 could be substituted for any of the B-series flights?

1.5 If your answer to 1.4 was yes, indicate which flight(s) you feel could be dropped in lieu of additional simulator training.

1.6 If your answer to 1.4 was yes, what type(s) of additional simulator training do you feel could be substituted for the B-series flights indicated in your response to 1.5?

1.7 If your answer to 1.4 was no, indicate the factors associated with T-29 in-flight training which cannot be compensated for by additional simulator training.

1.8 If your answer to 1.4 was no, suggest modifications to the simulator or the TPs which might make it possible to substitute simulator training for in-flight training.

1.9 What elements of present simulator training do you feel have the best value in preparing students for T-29 training flights?

1.10 What elements of present simulator training do you feel have the least value in preparing students for T-29 training flights?

1.11 Using the rating scale below, rate the concept of using Device 1D23 to train all students to at least the same, standardized performance levels prior to allowing them to advance to T-29 in-flight training.

| Very Undesirable | Possibly Undesirable | No Opinion | Possibly Desirable | Very Desirable |
|---|---|---|---|---|

1.12 Please feel free to make additional comments about training in Device 1D23 in preparation for T-29 in-flight training.

SECTION 2. IMPACTS OF TRAINING IN DEVICE 1D23 UPON STUDENT PERFORMANCE IN THE T-39 FLIGHT STAGE.

You should complete this section only if you were instructing in T-39 aircraft during the period (December 1972-January 1973), when training in Device 1D23 was initiated.

2.1 Overall, how much value do you feel training in Device 1D23 has been in preparing students for each T-39 training flight? Please make a rating for each flight. (Place an "x" squarely in categories).

| | Negative Value | No Value | Minimal Value | Moderate Value | High Value |
|---|---|---|---|---|---|
| C-1 | | | | | |
| C-2 | | | | | |
| C-3 | | | | | |

2.2 Using the rating scale on the following page, place "Xs" squarely within the ratings which best reflect your feelings about how well training in Device 1D23 prepares students for T-39 training flights.

Several task categories are presented. For each task category, please indicate your feelings about how well training in the simulator prepares students to execute the task category during T-39 training flights.

Your second task is to continue by making separate ratings for each task category.

Simply repeat the above procedure until you have completed all of the ratings. Then complete the questionnaire items on the following pages.

| | Hurts Greatly | Hurts Some | No Effect | Helps Some | Helps Greatly |
|---|---|---|---|---|---|
| **PREFLIGHT PLANNING & PREPARATION** | | | | | |
| Interpreting airways charts | | | | | |
| Selecting radio nav aids | | | | | |
| Preflighting logs | | | | | |
| Preparing flight plans | | | | | |
| **MEASURING AND COMPUTING** | | | | | |
| Determining TAS | | | | | |
| Determining ground speed | | | | | |
| Determining ETA | | | | | |
| Determining wind direction & velocity | | | | | |
| Determining drift angle | | | | | |
| **NAVIGATING** | | | | | |
| Understanding radials from nav aids | | | | | |
| Interpreting RMI | | | | | |
| Plotting accurate TACAN fixes | | | | | |
| Correctly applying drift angle | | | | | |
| Determining headings to fly | | | | | |
| Departure procedures | | | | | |
| Enroute procedures | | | | | |
| Turn point procedures | | | | | |
| Directing flight in holding pattern | | | | | |
| Approach procedures | | | | | |
| Fuel management | | | | | |
| Filling out logs | | | | | |
| Communicating with the pilot | | | | | |
| **COPILOT DUTIES** | | | | | |
| Interpreting flight instruments | | | | | |
| Interpreting engine instruments | | | | | |
| Performing checklist items | | | | | |
| Tuning radios | | | | | |
| Setting IFF codes | | | | | |
| Monitoring UHF radios | | | | | |
| Communicating with the ground | | | | | |
| Copying clearances | | | | | |
| **INTEGRATION OF KNOWLEDGE** | | | | | |
| Getting it all together | | | | | |
| Interpreting instruction | | | | | |
| Keeping oriented relative to aircraft position | | | | | |
| Keeping oriented relative to direction to checkpoints | | | | | |
| Pacing tasks to "keep ahead of the aircraft" | | | | | |

INTEGRATION OF KNOWLEDGE (continued)

| | Hurts Greatly | Hurts Some | No Effect | Helps Some | Helps Greatly |
|---|---|---|---|---|---|
| Anticipating what occurs in flight. . . . . . | | | | | |
| Understanding spatial relationships . . . . . | | | | | |
| Identifying incorrect Nav inputs/. . . . . . solutions | | | | | |
| Identifying procedural & computation. . . . . errors | | | | | |

2.3 Do you feel that additional training in Device 1D23 could be substituted for any of the present C-series flights?

2.4 If your answer to 2.3 was yes, indicate which flight(s) you feel could be dropped in lieu of additional simulator training _____.

2.5 If your answer to 2.3 was yes, what type(s) of additional simulator training do you feel could be substituted for the C-series flights indicated in your response to 2.4?

2.6 If your answer to 2.3 was no, indicate the factors associated with T-39 in-flight training which cannot be compensated for by additional simulator training.

2.7 If your answer to 2.3 was no, suggest modifications to the simulator or the TPs which might make it possible to substitute simulator training for in-flight training.

2.8 What elements of present simulator training do you feel have the best value in preparing students for T-39 training flights?

2.9 What elements of present simulator training do you feel have the least value in preparing students for T-39 training flights?

2.10 Using the rating scale below, rate the concept of using Device 1D23 to train all students to at least the same, standardized performance levels prior to allowing them to advance to T-39 in-flight training.

| | | | | |
|---|---|---|---|---|
| | | | | |
| Very Undesirable | Possibly Undesirable | No Opinion | Possibly Desirable | Very Desirable |

2.11 Please feel free to make additional comments about training in Device 1D23 in preparation for T-39 in-flight training.

## SECTION 3. DESIGN FEATURES OF DEVICE 1D23

You should complete this section only if you are qualified to instruct in Device 1D23.

3.1 When you instruct in Device 1D23, on the average, how many students at a time do you instruct during each of the following phases:

Pre-T-29 _____

Pre-T-39 _____

Pre-F-9 _____

3.2 How often do the above numbers of students seem to large for an individual to effectively instruct? Please respond for each phase shown below.

| | Never | Occasionally | Frequently | Always |
|---|---|---|---|---|
| Pre-T-29 | | | | |
| Pre-T-39 | | | | |
| Pre-F-9 | | | | |

3.3 In the above item, if you checked any response other than "never", please indicate the circumstances (TPs, problem areas, etc.) which make the student-to-instructor ratio seem too high.

Pre-T-29 Phase:

Pre-T-39 Phase:

Pre-F-9 Phase:

3.4 What problems, if any, have you experienced in using the communication link (ICS) between students and instructors?

3.5 Using the following rating scale, place an "x" in the category which best reflects your experience regarding the value of the computer printout of student performance for reconstructing the flight.

| No Value | Minimal Value | Moderate Value | High Value |
|---|---|---|---|
| | | | |

3.6 Using the following rating scale, place an "x" in the category which best reflects your experience regarding the value of the computer printout of student performance for <u>evaluating student proficiency</u>.

| No Value | Minimal Value | Moderate Value | High Value |
|---|---|---|---|
| | | | |

3.7 From an instructor's standpoint, what are three of the most important improvements which could be made to the design of Device 1D23?

3.8 From an instructor's standpoint, what are three of the most desirable design features which are incorporated in Device 1D23?

3.9 This item addresses the period when students are first introduced to Device 1D23 and begin to receive training in the device (e.g. TPs 1-4). Using the rating scale below, place "Xs" in the appropriate columns to indicate your assessment of the degrees of difficulty which students experience in each of the areas listed.

| | Levels of Difficulty | | | |
|---|---|---|---|---|
| | None | Little | Moderate | High |
| Identifying uses of each cockpit functional area | | | | |
| Interpreting digital readout displays | | | | |
| Using keyboards for data inputs | | | | |
| Learning requirements and procedures for control of simulator | | | | |
| Communicating with TDOs | | | | |
| Communicating with INFOs | | | | |

3.10 Please describe any other areas where students appear to have difficulty when they first begin to use Device 1D23.

3.11 Please feel free to make any additional comments about the design of Device 1D23.

# APPENDIX C

## SYNOPSIS OF MULTIVARIATE STATISTICS TESTS

## MULTIVARIATE STATISTICS

Experiments involving complex human performance often incorporate a battery of performance measures in an attempt to reasonably describe the variety of complex human behaviors involved. As a result, the researcher may be faced with a difficult data analysis task and often may experience a considerable challenge in integrating voluminous information into meaningful forms.

A multivariate data analysis technique was used in this study because it provided a means of consolidating experimental data, composed of a variety of measures, into a single analysis. The multivariate analysis provided a statistical test which was based on a composite measure. The composite measure was based on a linear combination. Weightings in the linear combination had been designed to produce a composite measure which would optimally discriminate between experimental groups.

The alternative approach, the univariate method, requires analysis of each measure separately. The researcher must then combine results of the separate analyses.

Computer analysis methods employed in this study were designed to give both multivariate and univariate test results. Accordingly, the following information was available:

> A statistical test (F-test) for composite measurement (measurement which combined the original measures to provide optimum discriminability between experimental groups)
>
> A separate statistical test (F-test) for each measure

## FACTORIAL DISCRIMINATION ANALYSIS

The specific statistical analysis technique used was based on a method called Factorial Discriminant Analysis (FACDIS) by Cooley and Lohnes (Ref 5). The technique combined a multiple discriminant analysis (best linear functions of measures for describing group differences) with a two-way factorial analysis of variance. In the multiple discriminant analysis, the loadings of each measure on each discriminant function were output. This was done so that, if groups were found to be significantly different, the differences could be interpreted in terms of the relative loadings of measures which contributed most to discriminating between groups.

ANALOGY TO UNIVARIATE STATISTICAL METHODS. The univariate analysis of variance involves the computation of sum of squares for each experimental comparison and for an experimental error; similar computations compose the multivariate analysis of variance except, instead of sums of squares, sums of squares and cross products (SSCP) matrices are computed. The sums of squares for each measure appears on the diagonal, while the sums of cross products between all possible pairs of measures are off the diagonal. Consequently, the mechanics of the two methods are similar, one involving sums of squares, the other SSCP matrices.

In the univariate method, sums of squares are divided by number of degrees of freedom to produce mean squares (MS), and, an F-ratio is formed by dividing the MS for an experimental treatment by the MS for experimental error. For the multivariate approach (one-way), the determinant for the within - SSCP ($|W|$) is divided by the determinant for the total - SSCP ($|T|$). Determinants of matrices are used instead of mean square computations; otherwise the approaches are similar. The result of the ratio of determinants has been termed WILKS' LAMBDA after the inventor of this statistic. There is, however, a transformation of the Wilks' Lambda statistic to produce an approximation of the conventional F statistic. Thus, one can test statistical significance using the common tables for the F distribution.

ONE-WAY MULTIVARIATE TEST (MANOVA). While a factorial analysis was conducted, a one-way multivariate analysis of variance program (MANOVA) was used to compute basis matrices needed for the factorial discriminant analysis program (FACDIS). The total SSCP matrix (deviations of all subjects from the grand centroid) was computed; this variance was then partitioned into "among-groups" and "within-groups" parts:

T (total) = A (among-groups) + W (within-groups). The T and W matrices, along with a complete set of centroids, are used as input for the FACDIS program.

The MANOVA program also computes an extension of Bartlett's test of homogeneity of variance (equality of group dispersion matrices).

TWO-WAY MULTIVARIATE ANALYSIS OF VARIANCE (FACDIS). The factorial model used by the FACDIS program is

$$T = Ar + Ac + Ai + W$$

where T, Ar, Ac, Ai and W are the total, among-rows, among-columns, interaction and within-groups sums of squares and cross-products matrices. The test criteria were:

| | |
|---|---|
| hypothesized row effect | $\Lambda r = \|W\|/\|Ar + W\|$ |
| hypothesized column effect | $\Lambda c = \|W\|/\|Ac + W\|$ |
| hypothesized interaction effect | $\Lambda i = \|W\|/\|Ai + W\|$ |

Vertical bars in the equations indicate determinants of the enclosed matrices. For each $\Lambda$ (Wilks' Lambda), an approximate F - ratio was computed, along with degrees of freedom, to allow table lookup in the same way as for univariate analysis of variance.

# APPENDIX D

## QUESTIONNAIRES
## COMPLETED AFTER FLIGHTS

## STUDENT POST-FLIGHT QUESTIONNAIRE

Student's Name ______________________________________________

Were you lead Nav this flight? Yes No

Circle this Flight B1 B2 B3 B4 C1 C2 C3

Your responses to the following items will in no way influence your flight grades. Please respond to all items frankly and openly.

1. Indicate your overall estimate of your performance on this flight. Place an "X" squarely in one category.

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| Unacceptable | Marginally Acceptable | Below Average | Average | Above Average | Very Good | Outstanding |

2. Indicate the degree of confidence which you felt in performing the following tasks during this flight:

| | None | Low | Moderate | High |
|---|---|---|---|---|
| *Communicating with ground. . | | | | |
| Using the computer . . . . . | | | | |
| Plotting fixes . . . . . . . | | | | |
| D R ahead . . . . . . . . . | | | | |
| Determining winds. . . . . . | | | | |
| Giving pilot headings. . . . | | | | |
| Determining ETAs . . . . . . | | | | |
| Making log entries . . . . . | | | | |

3. Indicate your overall estimate of how well you will do on your next training flight. Place an "X" squarely within one category.

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| Unacceptable | Marginally Acceptable | Below Average | Average | Above Average | Very Good | Outstanding |

* T-39 Flights Only

STUDENT CRITIQUE FORM
(Completed by Instrustors)

Student Name ________________ INFO/IP Name ________________

Was studen lead Nav this flight? Yes No

Circle this Flight
B1 B2 B3 B4 C1 C2 C3

1. Was the student ever disoriented to the point that he appeared unsure of his present position? Yes No

2. How many times did the student ask for help? ___

3. How many times did you have to intercede to help the student overcome navigation task errors? ___

4. How many times was the student unable to interpret your instructions? ___

5. Indicate your overall estimate of the student's performance relative to the performance level you generally observe for this flight. Place an "X" squarely within one category.

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| Unacceptable | Marginally Acceptable | Below Average | Average | Above Average | Very Good | Outstanding |

6. Please estimate the amount of hesitation the student exhibited in performing the following tasks.

| | None | Low | Moderate | High |
|---|---|---|---|---|
| *Communicating with ground. . . | | | | |
| Using the computer . . . . . . | | | | |
| Plotting fixes . . . . . . . . . | | | | |
| D R ahead . . . . . . . . . . | | | | |
| Making log entries . . . . . . | | | | |

7. Indicate your overall estimate of how well this student will do on his next training flight. Place an "X" squarely within one category.

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| Unacceptable | Marginally Acceptable | Below Average | Average | Above Average | Very Good | Outstanding |

* T-39 Flights Only

# APPENDIX E

## CONTENT OF DEVICE 1D23 EVALUATION STUDENT QUESTIONNAIRE

The following questionnaire items are intended to allow you - the student - to critique various design features of Device 1D23. Your comments will be of considerable value to the Chief of Naval Training by providing guidelines regarding desirable design features (which can be included in future training devices) and undesirable design features (which should be avoided in future training devices).

Your comments on this questionnaire will remain anonymous. Please feel free to express your viewpoints openly.

Please feel free to write in additional comments wherever you feel they are appropriate.

1. What is the most advanced Training Problem (TP) on which you have received instruction? ____

2. What problems, if any, have you experienced in using the communication link (ICS) between yourself and the instructor?

3. What problems, if any, have you experienced in using the communication link (ICS) between yourself and the TDO?

4. Using the following rating scale, place an "X" in the category which best reflects your experience regarding the value of the computer printout of student performance for <u>reconstructing the flight</u>.

| | | | |
|---|---|---|---|
| No Value | Minimal Value | Moderate Value | High Value |

5. Using the following rating scale, place an "X" in the category which best reflects your experience regarding the value of the computer printout of student performance for <u>evaluating how well you did</u>.

| | | | |
|---|---|---|---|
| No Value | Minimal Value | Moderate Value | High Value |

6. From a student's standpoint, what are three of the most important improvements which could be made to the design of Device 1D23?

7. From a student's standpoint, what are three of the most desirable design features which are incorporated in Device 1D23?

8. This item addresses the period when you were first introduced to Device 1D23 and began to receive training in the device (e.g. TPs 1-4). Using the rating scale below, place "Xs" in the appropriate columns to indicate your assessment of the degrees of difficulty which you experienced in each of the areas listed.

| | Levels of Difficulty | | | |
|---|---|---|---|---|
| | None | Little | Moderate | High |
| Identifying uses of each cockpit functional area | | | | |
| Interpreting digital readout displays | | | | |
| Using keyboards for data inputs | | | | |
| Learning requirements and procedures for control of the device | | | | |
| Communicating with TDOs | | | | |
| Communicating with INFOs | | | | |

9. Please describe any other areas where you have experienced difficulty because of the way Device 1D23 was designed.

10. Please feel free to make any additional comments about the design of Device 1D23.

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